

DISSERTATION

Titel der Dissertation

„Feeling the fluency: Exploring the subjective experience
of processing fluency“

Verfasser

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angestrebter akademischer Grad

Doktor der Naturwissenschaften (Dr. rer. nat)

Wien, 2015

Studienkennzahl lt. Studienblatt: A 791 298

Dissertationsgebiet lt. Studienblatt:
Psychologie

Betreuerin / Betreuer: Univ.-Prof. Dr. Helmut Leder

Publications included in this thesis

Forster, M., Gerger, G., & Leder, H. (2015). *Everything's relative? Relative differences in processing fluency and the effects on liking*. Manuscript submitted for publication.

Forster, M., Leder, H., & Ansorge, U. (2013). It felt fluent, and I liked it: Subjective feeling of fluency rather than objective fluency determines liking. *Emotion, 13*, 280-289.
doi:10.1037/a0030115

Forster, M., Fabi, W., & Leder, H. (2015). Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation. *Frontiers in Human Neuroscience, 9*:373. doi: 10.3389/fnhum.2015.00373

Forster, M., Leder, H., & Ansorge, U. (2015). *Exploring the subjective feeling of fluency*.
Revised manuscript submitted for publication.

Jakesch, M., Leder, H., & Forster, M. (2013). Image ambiguity and fluency. *PloS ONE, 8*, e74084. doi: 10.1371/journal.pone.0074084

Gerger, G., Forster, M., & Leder, H. (2015). *It felt fluent but I did not like it – Fluency effects in faces vs. patterns*. Manuscript in revision.

Conference contributions connected to this thesis

Forster, M., Jakesch, M., Goller, J., & Leder, H. (2014). *The pleasure of ambiguity*. Talk at the 23rd IAEA Congress on Empirical Aesthetics, New York, USA.

Gerger, G., Forster, M., & Leder, H. (2014). *It felt fluent, but I did not like it: Fluency effects in faces*. Poster at the 9th PPRU Workshop, Jena, Germany.

Forster, M., Fabi, W., & Leder, H. (2014). *Subjective fluency influences liking*. Talk at the 56th Conference of Experimental Psychologists (TeaP), Gießen, Germany.

Forster, M., Gerger, G., Jakesch, M., & Leder, H. (2013). *Fluency needs uncertainty*. Talk at the 18th European Society for Cognitive Psychology Meeting (ESCOP), Budapest, Hungary.

Forster, M., Gerger, G., & Leder, H. (2013). *Fluency needs uncertainty*. Poster at the 36th European Conference on Visual Perception (ECVP), Bremen, Germany.

Forster, M., & Leder, H. (2013). *Subjective fluency and affective response*. Talk at the 55th Conference of Experimental Psychologists (TeaP), Vienna, Austria.

Forster, M., Leder, H., & Ansorge, U. (2012). *Subjective feeling of fluency and affective response*. Poster at the 35th European Conference on Visual Perception (ECVP), Alghero, Italy.

Forster, M., & Leder, H. (2012). *Subjective fluency and aesthetic preference*. Talk at the 54th Conference of Experimental Psychologists (TeaP), Mannheim, Germany.

Forster, M., & Leder, H. (2011). *Does fluency really feel fluent? A preliminary research approach*. Poster at the 4th Vienna Aesthetics Symposium: Neuroaesthetics, Vienna, Austria.

Further publications during the PhD study

Forster, M. (2014). The Aesthetic Brain: How We Evolved to Desire Beauty and Enjoy Art.

Psychology of Aesthetics, Creativity, & the Arts, 8, 260-261. doi: 10.1037/a0036401

Carbon, C.-C., Faerber, S. J., Gerger, G., Forster, M., & Leder, H. (2013). Innovation is

appreciated when we feel safe: On the situational dependence of the appreciation of

innovation. *International Journal of Design*, 7, 43-51.

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eyeglasses on perception, recognition, and impression of faces. *Swiss Journal of*

Psychology, 70, 211-222. doi: 10.1024/1421-0185/A000059

Abstract

According to the theory of processing fluency higher ease-of-processing is a cue for evaluations of objects (see Alter & Oppenheimer, 2009b, for a review). Despite a multitude of studies and a number of theoretical models of processing fluency, questions about the exact working of the process are still unresolved or vary with the theoretical model. Thus, in this thesis the main open questions and discrepancies of how processing fluency influences evaluations of liking are addressed. Especially, the role of the subjective feeling of fluency, i.e., the experience of higher ease-of-processing, has not yet been satisfactorily addressed. All models of processing fluency propose that higher ease-of-processing at different processing stages leads to a higher fluency. This fluency then is used as a source for evaluations. However, the main discrepancies revolve around whether the experience of processing fluency is consciously accessible or not (Reber, Fazendeiro, & Winkielman, 2002b); if it is conscious, whether this is detrimental for fluency effects (Bornstein & D'Agostino, 1992, 1994); or whether the experience of fluency is affectively positive (Winkielman, Schwarz, Fazendeiro, & Reber, 2003) or an unspecific activation (Bornstein & D'Agostino, 1992, 1994). Six contributions show that the experience of processing fluency is consciously accessible and that this conscious experience is not detrimental for fluency effects. In all contributions participants reported higher feelings of fluency with higher ease-of-processing (most thoroughly addressed in Publications 2 and 3). In Publication 4 it was shown that individuals seem to use the feeling of fluency as a source for especially positive stimulus evaluations. Nonetheless, no clear physiological reactions to higher ease-of-processing were found. This indicates that fluency might be more an experience of cognitive processes than a strong affective reaction (see also Greifeneder & Unkelbach, 2013). However, the feeling is robust across variations in experimental context. Feelings of fluency were influenced when ease-of-processing was either varied within- or between-participants (Publication 1). Using more complex stimuli (artworks and faces), the limits of the fluency-liking link could be

shown. Ambiguous (disfluent) artworks were liked more than non-ambiguous (fluent) artworks when there was enough time to indulge in the challenge of ambiguity (Publication 5). Furthermore, with increasing fluency faces were liked less (Publication 6). Thus, with more complex stimuli, fluency is but one source for liking (see also Leder, Belke, Oeberst, & Augustin, 2004). Together the findings in this thesis confirm that fluency is a metacognitive cue for evaluations of objects. Especially, when the viewing conditions are suboptimal, i.e. under short presentation durations, higher fluency is strongly influencing the evaluation. This thesis contributes to the current knowledge by showing that conscious insight into the ease-of-processing is possible and far from detrimental for effects of fluency on evaluations.

Acknowledgements

First and foremost I want to thank my advisor Helmut Leder, who supported me in all decisions as an ideal supervisor and mentor would do. He always had an open ear (and door) for my questions. I will always remember and cherish his first comment to an answer I gave to one of his questions back when I was an undergraduate: “It is fine that you might believe this is the reason for the effect. But here [at the University] we do not take much on what you believe; it is rather what research has shown.” I am also grateful to Ulrich Ansorge who, at an early stage of this project, had the simple, yet ingenious, idea to just directly ask participants what they feel.

Then, I want to thank all my colleagues who endured my presentations and my enthusiasm about the theory of processing fluency. I especially want to thank Gernot Gerger, Jürgen Goller, and Matthew Pelowski for proofreading the thesis. All remaining errors are my sole responsibility.

To my parents: Thank you so much for the constant and endless support in every respect.

Finally, to my loved ones, Elke and Lukas: Thank you endlessly for always having my back and supporting me in everything I do.

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General Introduction

Few everyday judgments and decisions are made with full information and without uncertainty. Individuals are often faced with some uncertainty regarding outcomes and possible choices (Kahneman, Slovic, & Tversky, 1982). For example, when we are choosing between two very similar objects and when we simply cannot decide (Schwarz, 2004, 2011); but also in situations where the need to take fast decision or cognitive demands are high (Herzog & Hertwig, 2013; Jiang & Hong, 2014). Uncertain decisions may be influenced by various incidental cues. One of these incidental cues biasing our judgments and decisions is processing fluency, or the ease-of-processing within our experience¹.

The main tenet of the theory of processing fluency is that the easier something can be processed, the higher or more positive it is evaluated. Processing fluency has been shown to influence a number of evaluations. Alter and Oppenheimer (2009b, pp. 221-222, Table 1) comprehensively summarize the main variables influenced by fluency. Variables most thoroughly explored in previous research include liking (e.g., Forster, Leder, & Ansorge, 2013; Reber, Winkielman, & Schwarz, 1998), truth (e.g., Dechêne, Stahl, Hansen, & Wänke, 2010; Reber & Schwarz, 1999), and familiarity/recognition (e.g., Lloyd et al., 2015; Westerman, 2008; Whittlesea, 1993).

The straightforward and simple relation between higher fluency and higher evaluations—especially of liking—makes the fluency theory very attractive in the fields of aesthetic appreciation, decision making, and consumer research (see for example, Labroo, Dhar, & Schwarz, 2008; Landwehr, Labroo, & Herrmann, 2011; Lee & Labroo, 2004). In the

¹ In the literature processing fluency is generally defined as the ease-of-processing. As I consider the *ease-of-processing* a more tangible term, it is henceforth used when describing manipulations of fluency. The term *fluency*, on the other hand, is used when referring to the concept. Please note that the term *fluency* throughout this thesis needs to be distinguished from the common vernacular use of *fluency*, the mastery of a language or activity. In this thesis, the term *fluency* always refers to the ease-of-processing a stimulus; thus, the terms *processing fluency* and *fluency* denote the same concept.

research field of empirical aesthetics, processing fluency is discussed as one possible construct explaining aesthetic appreciation of art (Bulot & Reber, 2012; Consoli, 2014; Graf & Landwehr, 2015; Leder, 2001; Reber, Schwarz, & Winkielman, 2004).

In this thesis, this link between fluency and liking will be the main focus of research interest, with a further emphasis on its implications for empirical aesthetics. The theoretical contributions derived from research on the fluency-liking link, are also applicable to general effects of metacognitive cues on evaluations, such as effects of fluency on truth (Dechêne et al., 2010).

However, there are also situations where the simple relation between fluency and liking does not always hold (see Gerger, Forster, & Leder, 2015; Jakesch, Leder, & Forster, 2013). Take for example Leonardo da Vinci's Mona Lisa. Compared to a doodle of a stick figure, the Mona Lisa is definitely harder to perceive. However, most people will also claim that rather they like or prefer the Mona Lisa. This can be explained by a model of aesthetic appreciation introduced by Leder et al. (2004). The model suggests that processing fluency is only one factor influencing preference formation and decision making. Nonetheless, there are numerous situations where processing fluency might be the dominating factor. Think for example of being in limbo between two similar alternatives or answering a question when you have not even the slightest idea of the correct answer. In such cases, the key factor for a decision can be a seemingly mundane perceptual characteristic, such as the ease to perceive the object (Reber & Schwarz, 1999). Thus, in situations where decisions are either difficult or uncertain (Lee, 2001), individuals rely on the fluency for their judgments.

The functional underpinnings of processing fluency are yet not fully understood. Previous research either studied the effects of ease-of-processing on various dependent variables (for a review see Alter & Oppenheimer, 2009b) or the concept of processing fluency was used to explain effects in experiments that were not designed for testing fluency (for

example Freddi, Cretenet, & Dru, 2013; or Niimi & Watanabe, 2012). Furthermore, there are a number of contributions that aimed to review and theoretically build a model of how processing fluency works (Albrecht & Carbon, 2014; Alter & Oppenheimer, 2009b; Bornstein & D'Agostino, 1994; Graf & Landwehr, 2015; Greifeneder, Bless, & Pham, 2011; Halberstadt & Hooton, 2008; Reber, Schwarz, et al., 2004; Unkelbach & Greifeneder, 2013; Whittlesea & Williams, 2001a, 2001b). All these theoretical approaches to processing fluency propose that higher ease-of-processing in early perceptual or later conceptual levels leads to a higher processing fluency and this fluency is used as a source for evaluations. Different theories emphasize different aspects of this process and are less specific at others. This leads to some discrepancies among the models. The main discrepancies revolve around (a) whether the experience of processing fluency is conscious or not (Reber et al., 2002b); if it is conscious, whether this is detrimental for the fluency effect (Bornstein & D'Agostino, 1992, 1994); or (b) whether the experience of fluency is of positive affect (Winkielman et al., 2003) or an unspecific activation (Bornstein & D'Agostino, 1992, 1994). Furthermore, the role of the subjective feeling of fluency, the affective component of fluency, has not yet been satisfactorily addressed.

Therefore, addressing these open points in this thesis is essential for understanding the link between fluency and evaluations. In the following the theories of processing fluency will be elaborated and hypotheses for each of our contributions will be derived from each of these theories.

Defining processing fluency

As Greifeneder and Unkelbach (2013, p. 2) aptly put it, “although people are familiar with fluency experiences, what exactly fluency is as a scientific concept may still be blurry.” They in turn propose five main characteristics of fluency: 1) fluency is a feeling, 2) fluency is a by-product of mental operations, 3) fluency informs us about the ease or difficulty of mental

operations as well as 4) whether something is easy or difficult depends on prior experience, and 5) fluency is the summed experience of all mental activity accompanying the processing a current stimulus. To put it shortly, fluency is the feeling resulting from the ease or difficulty in processing a stimulus in relation to prior experience.

Theories of processing fluency

Historically, the concept of processing fluency has its origins in the work of Jacoby and colleagues, who used it to explain recognition in memory research (for an overview see Jacoby, Kelley, & Dywan, 1989). They argue that recognition is the result of a stimulus being relatively more fluent than another stimulus. This experience leads a person to infer that processing fluency stems from prior experience; thus, for fluent processing situations, the stimulus must have been encountered before (Jacoby & Dallas, 1981).

The discrepancy attribution hypothesis

Building on the works of Jacoby and colleagues, Whittlesea and Williams formulated the *discrepancy-attribution hypothesis* (Whittlesea & Williams, 2000, 2001a, 2001b). In the realms of recognition memory, they explained feelings of familiarity. Those feelings arise from a comparison of the actual fluency in processing to an expectation of fluency. If the experience of fluency is higher than expected (i.e. *discrepant*) then an *attribution* process is triggered (see also Jiang & Hong, 2014). When this experience of fluency is attributed to prior encounters, feelings of familiarity arise. However, it remains unclear how exactly the expectation of fluency is achieved. For example, which reference frame do participants apply in judging fluency?

To shed light on this issue we conducted two experiments in the realms of processing fluency (publication: **Everything's relative? Relative differences in processing fluency and the effects on liking**). We manipulated the ease-of-processing either between-

participants or within-participants. When ease-of-processing is manipulated within-participants, the feeling of fluency could be based on an internal reference (i.e., how easy/difficult the stimulus is expected to be processed, as Whittlesea and Williams suggested). On the other hand, the feeling of fluency could be based on a comparison of ease-of-processing of a current stimulus relative to previously presented stimuli. This means, the presence of other stimuli that differ in ease-of-processing from the current stimulus is necessary for feelings of fluency. Crucially, in a between-participants manipulation of ease-of-processing, participants only see high or low fluent images, thus the evaluation of felt fluency can only be based on an internal reference. The results show that felt fluency can be evaluated regardless of the ease-of-processing manipulation being between or within-participants. This suggests that participants can evaluate fluency in a rather absolute manner, possibly comparing the experience of fluency to an internal reference of expected fluency (see also Whittlesea & Leboe, 2003). Interestingly, the manipulation was sensitive to the link between fluency and liking. Only in the within-participants manipulation higher ease-of-processing led to higher liking. When manipulating the ease between participants then liking did not increase. These findings suggest that the feeling of fluency is only used as a source for liking evaluations when there is a variation in ease-of-processing among presented stimuli. Without a strong (experimentally manipulated) variation in ease-of-processing, the salience of the fluency feeling may not have been high enough to be applied as a source of information (see also Unkelbach & Greifeneder, 2013). Nonetheless, the experiments could corroborate the idea that an internal reference frame is sufficient for feelings of fluency.

Perceptual fluency/attributional account

While the discrepancy-attribution hypothesis can explain why a stimulus is familiar or how feelings of fluency arise, it is less specific about how fluency is attributed to evaluations. In their *perceptual fluency/attributional account*, Bornstein and D'Agostino (1992, 1994)

argue that higher ease-of-processing results in an *unspecific activation* which is then attributed to the stimulus. Thus, if participants have to indicate, for example, how much they like a stimulus, then the activation resulting from higher ease-of-processing may be falsely interpreted as higher liking. In line with this notion, previous studies showed that higher ease-of-processing can be attributed to a range of evaluations, such as brightness/darkness (Mandler, Nakamura, & Van Zandt, 1987), loudness (Jacoby, Allan, Collins, & Larwill, 1988), familiarity (Whittlesea, 1993), or truth (Reber & Schwarz, 1999). The unspecific activation has, however, not been empirically shown. Furthermore, ensuing experiments could not corroborate that higher ease-of-processing leads to higher evaluations, regardless of the rating dimension: Reber et al. (1998) for example found that higher ease-of-processing leads to higher liking, but not to higher disliking, as the perceptual fluency/attributional account would suggest (but see Albrecht & Carbon, 2014). Furthermore, Winkielman and Cacioppo (2001) found that higher ease-of-processing leads to positive affective reactions, indicated by facial muscle activation (see also Gerger, Leder, Tinio, & Schacht, 2011; Topolinski, Likowski, Weyers, & Strack, 2009). These findings led to the hypothesis that processing fluency itself is hedonically marked (Reber, Schwarz, et al., 2004; Winkielman et al., 2003).

The hedonic marking of processing fluency

According to this approach, higher fluency signals a positive state of affairs, progress towards successful recognition, and error-free processing (Reber, Schwarz, et al., 2004, p. 366; Song & Schwarz, 2009). This positivity is then subjectively perceived as a feeling of fluency, which is attributed to the stimulus, resulting in more positive evaluations (e.g., Forster et al., 2013; Reber, Wurtz, & Zimmermann, 2004; Regenber, Häfner, & Semin, 2012; Wurtz, Reber, & Zimmermann, 2008).

This proposed process is also in line with the suggested process underlying a *mere-exposure effect* (Bornstein, 1989; Butler & Berry, 2004; Zajonc, 2001). This effect describes

the finding that liking of repeatedly presented stimuli increases. In the line of classical conditioning, Zajonc (2001) argued that with stimulus presentation individuals also assess the absence (positive) or presence (negative) of aversive events. If a stimulus has been presented before without any aversive consequence, then at repeated presentation this absence is recalled and the stimulus is liked more. As repeated presentation can also be seen as a form of higher fluency, the explanations for mere exposure can be applied to processing fluency.

Thus, in contrast to the perceptual fluency/attributional account, in this account fluency is affectively positive (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001). Though first attempts have been made to gather empirical evidence backing one of the models (Fang, Singh, & Ahluwalia, 2007; Zebrowitz & Zhang, 2012), the picture is still blurry. To clarify this issue we conducted two experiments which specifically measured affective responses on a behavioral and physiological level (publication: **Exploring the subjective feeling of fluency**). We first tested whether experiences of fluency are behaviorally rather attributed to valence (negative – positive, as indicated by the account of hedonic marking) or to arousal (less – more arousing, as indicated by the perceptual fluency/attributional account). We furthermore tested whether manipulations of ease-of-processing show effects in facial muscle activation (fEMG, Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001) or in skin conductance response (SCR, Morris, Cleary, & Still, 2008). Measures of fEMG allow capture of subtle changes in positive/negative valence. Measures of SCR allow capture of the arousal level of participants. Thus, these two measures allow testing of whether fluency is affectively positive or an unspecific activation.

Another difference between the account of hedonic marking and the perceptual fluency/attributional account concerns the experience of fluency itself. The account of hedonic marking suggests that ease-of-processing is experienced as a subjective feeling of

fluency (Forster et al., 2013; Reber, Wurtz, et al., 2004; Regenberg et al., 2012). Previous research has addressed the feeling of fluency by testing experienced readability (Reber, Wurtz, et al., 2004) or by separately asking for feelings of fluency and liking (Topolinski & Strack, 2009c). What complicates the assessment of feelings of fluency, however, is that fluency “is typically experienced at the periphery of the conscious awareness, resulting in a vague or ‘fringe’ experience of ease” (Reber, Fazendeiro, & Winkielman, 2002a, p. 3; Reber & Schwarz, 2002). Indeed, previous research has shown that effects of processing fluency on liking are even possible without conscious feelings of fluency (Topolinski & Strack, 2009c). Additionally, making participants explicitly aware of the manipulation of processing fluency or offering a plausible source for their feelings of fluency attenuates or even may obliterate the effect of processing fluency on evaluations (so-called discounting, Bornstein & D’Agostino, 1994; but see Newell & Shanks, 2007). To more thoroughly shed light on whether and how a subjective and conscious feeling of fluency affects evaluations, we performed a number of studies asking participants how easy it was to process a stimulus, thus capturing the subjective feeling of fluency. First, we showed that participants in general have a conscious feeling of fluency (publication: **It felt fluent, and I liked it: Subjective feeling of fluency rather than objective fluency determines liking**). In this study, manipulations in ease-of-processing through subliminal contour priming (Experiment 1), and through variations in presentation duration (Experiment 2), led to higher felt fluency. Second, we could also show that felt fluency predicted liking even more strongly than the actual manipulation of ease-of-processing. Thus, the easier a person *feels* something is processed, the more it is liked. These findings were subsequently also corroborated in a follow-up study (publication: **Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation**), in which we manipulated the conscious representation of felt fluency by giving participants false feedback about their ease-of-processing. The results showed that false feedback of a high ease-of-processing experience led to higher liking evaluations when

compared to false feedback of a low ease-of-processing experience. This confirmed that the feeling of fluency can indeed be a source for evaluations. Furthermore, as participants were fully made aware of their subjective feeling, the findings also show that awareness of the fluency experience does not harm the effects on evaluations (see also Newell & Shanks, 2007). Taken together, the experiments show that participants can directly report their feelings of fluency, and these feelings are related to liking.

In line with previous research, these studies used rather simple stimulus material—line drawings of common objects such as a dog, a spoon, or an anchor (Rossion & Pourtois, 2004). Effects of ease-of-processing are however more fragile when more complex stimulus material is used (Gerger et al., 2015; Jakesch et al., 2013, both in this thesis). Processing fluency may be a central element in the aesthetic appeal of complex stimuli, such as artworks or musical pieces; however, empirical evidence is still scarce (see Margulis, 2013; Nunes, Ordanini, & Valsesia, 2015; Schellenberg, Peretz, & Vieillard, 2008, for exceptions in music). Only few studies have shown that higher ease-of-processing indeed influences appreciation of visually more complex material such as art (Halberstadt & Hooton, 2008; but see Leder, 2001). Halberstadt and Hooton (2008) could show that analytic thought about the stimuli affected the link between fluency and liking. The results led them to propose the *affect disruption hypothesis*.

The affect disruption hypothesis

This hypothesis extends previous theories on fluency by showing that analytic thought—reasoning about the causes of one’s own attitudes—interferes with the effects of metacognitive cues such as the effects of fluency. Indeed, other findings have corroborated these results, showing that both thinking about one’s own attitudes and decisions (Halberstadt & Catty, 2008) and abstract thinking (Tsai & Thomas, 2011) attenuate effects of ease-of-

processing. However, compared to previous and subsequent theoretical approaches, the affect disruption hypothesis offers only a small refinement of the advances in fluency research.

Nonetheless, the focus on analytic thinking is noteworthy. The relationship between analytic thinking and ease-of-processing is reciprocal. Not only does analytic thinking attenuate effects of ease-of-processing, lower ease-of-processing, or disfluency, does promote analytic thinking (Alter, Oppenheimer, & Epley, 2013; Alter, Oppenheimer, Epley, & Eyre, 2007; Song & Schwarz, 2008). It is argued that difficulty in processing signals that something is odd and closer attention should be paid to the stimulus, which promotes more analytic processing (Alter et al., 2007). Indeed, a recent account of processing fluency incorporates this line of thought (the Pleasure-Interest Model of Aesthetic Liking, Graf & Landwehr, 2015, see below). This relationship between analytic thinking and ease-of-processing might help explaining processing fluency. Given that higher ease-of-processing is accompanied by a feeling, which is an affective process, analytic thinking, which is a cognitive process, might attenuate the affect. Thus, the awareness of cognition might weaken the affective processing and consequently the effect of fluency. However, this hypothesis remains to be tested.

A further explanation for fluency effects also specifically addresses the affective processing: the *fluency amplification model* (Albrecht & Carbon, 2014).

The fluency amplification model

Similar to the affect disruption hypothesis, this model by Albrecht and Carbon (2014) spawned from results inconsistent with the previous formulations of processing fluency—especially regarding affective reactions. If fluency is per se positive, then this should lead to less negative reactions to negative stimuli. Thus, previous accounts of fluency would suggest that negative stimuli, such as spiders, snakes, or even mutilations, might become less negative with higher ease-of-processing (see Reber, Schwarz, et al., 2004, p. 375). Using positive,

neutral, and negative pictures of the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 2008), Albrecht and Carbon (2014) showed that higher processing fluency through contour priming led to an amplification of the affective tone of a stimulus. That is, positive IAPS pictures were rated more positive and negative IAPS pictures more negative, respectively, with higher processing fluency. Neutral IAPS pictures were not affected by manipulations. Thus, these results were incompatible with previous accounts of fluency being per se positive. They were rather in line with the perceptual fluency/attributional account (Bornstein & D'Agostino, 1992, 1994), but limited to effects on stimuli with a pronounced affective tone. The finding that neutral images were not affected by manipulations of ease-of-processing is surprising, as previous research showing effects has mostly been conducted using neutral, albeit more simple, material. It is possible that the high variation in affective tone of the IAPS pictures overshadows the subtle effects of processing fluency on neutral stimuli. Thus, this model of fluency as well is not fully compatible with previous findings.

A general model of fluency effects in judgment and decision making

Unkelbach and Greifeneder (2013) offered a more general, but also more comprehensive, framework of processing fluency. Inspired by Brunswicks' lens model (Brunswik, 1952, 1956), which explains how an organism processes the environment, they proposed that processing fluency is used as a cue for evaluations because it is a readily perceivable (proximal) cue for a not-directly-accessible (distal) criterion. Furthermore, they proposed three major steps in the process: *perception*, *attribution*, and *interpretation*. Following Whittlesea and Williams (2000, 2001a, 2001b), individuals are argued to continuously monitor their cognitive processes. Fluency is experienced, i.e. *perceived*, when a deviation in ease-of-processing occurs.

In turn, for fluency effects to occur, two further processes are important (Unkelbach & Greifeneder, 2013). First, fluency experience needs to be *attributed* to the current situation. Thus, fluency needs to be associated to the stimulus. This association is mainly driven by the salience of the fluency experience. The more salient the fluency cue in comparison to the other proximal cues, the more likely it is that fluency is associated with the stimulus.

Second, fluency needs to be *interpreted* as a cue for the distal criterion. If fluency is interpreted as a cue for another criterion, then effects do not occur. Indeed, previous research has shown the importance of interpretation. For example, following the processing fluency account, when individuals are asked to judge the frequency of surnames, famous names are more frequently experienced and thus fluent. This higher fluency is then used as a cue for frequency, thus the frequency of famous people's surnames should be overestimated. However, experiments have shown that this is not the case: Oppenheimer (2004) could show that frequency of famous people's surnames was underestimated. This is because higher ease-of-processing and the resulting fluency experience were interpreted as a cue for fame and not for frequency. Thus, higher fluency did not influence frequency estimation.

The above finding, however, raises the question of how individuals know that fluency is a cue for either fame or frequency? How do individuals know the meaning of fluency (see also Unkelbach & Greifeneder, 2013, p. 20)? According to Unkelbach and Greifeneder there are at least two possible sources: (a) individuals use naïve theories to assess the meaning of fluency (Schwarz, 2004). One of those theories suggests that what is easier to process must be more familiar (otherwise it would not be easy to process). Or, (b) individuals may learn the meaning of fluency through feedback learning. Previous research has shown that the meaning of fluency is malleable (Brinol, Petty, & Tormala, 2006; Unkelbach, 2006, 2007). Unkelbach impressively showed that fluency effects could be reversed by giving participants feedback that higher ease-of-processing signals unfamiliarity (2006, see also Olds & Westerman, 2012)

or falsehood (2007). Additionally, Reggev, Hassin, and Maril (2012) showed that, depending on task demands, not only the interpretation but also the extent to which fluency was relied upon could be influenced. When in a previous task reliance on fluency was detrimental for task performance, fluency effects in the subsequent task were more attenuated than when in a previous task reliance on fluency was helpful for task performance. Unkelbach and Greifeneder (2013, pp. 22-23) thus suggest the following distinction between naïve theories and feedback learning as sources for evaluations: Naïve theories do not change fluency experience, they rather influence how this experience is interpreted. Feedback learning already influences the experience of fluency.

In contrast to interpretation, there is, however, less empirical evidence for the importance of attribution of fluency to a situation. Only few studies have corroborated that fluency effects vanish when fluency is misattributed to another source. Schwarz et al. (1991), for example, showed that effects of ease-of-processing could be eliminated when the ease was attributed to background noise (see also Claypool, Hall, Mackie, & Garcia-Marques, 2008). Though Unkelbach and Greifeneder propose a distinction between interpretation and attribution, they themselves acknowledge that interpretation could also be seen as a form of attribution (2013, p. 24). Nonetheless, they argue that it is an advantage to distinguish the processes: attribution is ascribing a cause to the fluency experience; that is, stimulus properties are responsible for the experience. Interpretation is ascribing the fluency experience to a distal criterion, such as fame, frequency, or preference.

In contrast to this comprehensive and general account on fluency and evaluation, a more recent model by Graf and Landwehr (2015) specifically tries to explain the effect of fluency on liking. Their Pleasure-Interest Model of Aesthetic Liking (in short: PIA model) extends the framework by Reber, Schwarz, et al. (2004) and accounts for evidence that could not find a positive linear relationship between fluency and liking (see for example Hekkert,

Snelders, & van Wieringen, 2003; Landwehr, Wentzel, & Herrmann, 2013; Van den Bergh & Vrana, 1998). We could also show that processing fluency does not always lead to higher liking. In a first experiment (publication: **It felt fluent but I did not like it – Fluency effects in faces vs. patterns**) we showed that effects of higher ease-of-processing on liking could be replicated for abstract patterns (see also Gerger et al., 2011), but were reversed for faces. Higher ease-of-processing (manipulated through presentation duration) led to higher feelings of fluency for both patterns and faces. Liking evaluations, however, only increased for patterns. In faces, liking evaluations decreased. These findings suggest that longer presentation duration, and thus deeper processing, enables processing of more detail. Then especially the unattractive feature, such as skin blemish or irregular skin coloration, might become more apparent, which in faces leads to a decrease in liking.

Furthermore, in Jakesch et al. (2013) (publication: **Image Ambiguity and Fluency**) we addressed the contradictory finding that, in the arts, ambiguity, which by definition is disfluent, can be a source of pleasure (Gamboni, 2002). Manipulating the ambiguity and the presentation duration of artworks by René Magritte we showed that ambiguous artworks were evaluated as harder to process than non-ambiguous works, which is in line with processing fluency accounts. However, starting at presentation durations of 500ms and more, ambiguous artworks were liked more than non-ambiguous artworks. Importantly, the PIA model can account for these findings by offering a dual-process perspective on the link between processing fluency and liking.

Pleasure-Interest Model of Aesthetic Liking (PIA Model)

In the PIA model liking is the result of two distinct processes: an initial automatic process, where liking is mainly governed by processing fluency, and a subsequent controlled process that can overwrite the automatic response (Graf & Landwehr, 2015). Regarding the automatic process, the model fully corresponds to previous accounts of fluency. The

innovation lies in postulating a subsequent controlled process. This process, requiring cognitive effort and a motivation to further process the stimulus, is mainly triggered by negative feelings in the automatic process. In addition, the need for cognitive enrichment can trigger further processing of a stimulus. Indeed, previous research has shown that the personal need for structure, a construct similar to the need for cognitive enrichment, is positively correlated with mere exposure, which is adjacent to processing fluency (T. Hansen & Bartsch, 2001). Furthermore, the regulatory focus, another related motivational factor, has an impact on fluency effects. Participants in a prevention focus, which leads participants to focus on safety needs, showed stronger effects of ease-of-processing on liking than participants in a promotion focus, which leads participants to focus on needs for growth (Freitas, Azizian, Travers, & Berry, 2005; see also Gillebaart, Förster, & Rotteveel, 2012, for similar findings).

The main predictions of the PIA model are thus (Graf & Landwehr, 2015): (1) When the initial automatic processing results in positive affect and there is no motivation to further process the stimulus, *pleasure* results. This is similar to what previous accounts of processing fluency suggested. There are, however, further routes, which depend on the controlled processing stage. (2) When initial automatic processing results in negative affect, and/or when there is sufficient motivation to further process the stimulus, evaluation depends on the expectation of fluency and ability to reduce disfluency. If controlled processing is less difficult than expected, this reduction is then experienced as something positive. This positivity is ascribed to the controlled processing stage and results in *interest*. (3) If disfluency cannot be reduced then this results in *confusion*. Lastly, (4) if there is no need for disfluency reduction, but if an individual is motivated to further process the stimulus, this results in *boredom*. In general, the model is derived from solid empirical evidence. Due to its recency, studies directly testing the main claims of the model are still outstanding. Future research will thus show the validity of this account.

Perceptual vs. conceptual fluency

Manipulations of ease-of-processing can operate on different processing levels. By far the most common distinction is between *perceptual fluency* and *conceptual fluency* (Alter & Oppenheimer, 2009b). This distinction also involves the effects of early low-level visual properties (perceptual) and effects of later higher-level processing stages (conceptual). As indicated in this distinction, the main focus of processing fluency research is on the ease or difficulty of *visual* processing.

Manipulations of *perceptual fluency* aim to change physical features of the stimuli to render the stimuli easier or harder to perceive. Common manipulations of perceptual fluency include priming (e.g., Albrecht & Carbon, 2014; Forster et al., 2013; Reber et al., 1998), font readability (e.g., Alter & Oppenheimer, 2008, 2009a; Reber, Wurtz, et al., 2004), contrast (e.g., Reber & Schwarz, 1999; Reber et al., 1998; Unkelbach, 2006), or presentation duration (e.g., Forster et al., 2013; Reber et al., 1998; Reber, Zimmermann, & Wurtz, 2004; Winkielman & Cacioppo, 2001). Manipulations of presentation duration are sometimes seen as a separate subgroup of perceptual fluency, often referred to as *temporal perceptual fluency* (Alter & Oppenheimer, 2009b; Jakesch et al., 2013; Leder, 2000, 2003).

Manipulations of *conceptual fluency* operate at higher cognitive levels, thus conceptual fluency is sometimes also called *cognitive fluency* (Belke, Leder, Strobach, & Carbon, 2010). These manipulations aim to change either the conceptual or the semantic relations between stimuli. Common manipulations are priming of concepts with related concepts (e.g., Belke et al., 2010). In the verbal domain, priming is mostly achieved by using semantically related concepts (Labroo et al., 2008; Lee & Labroo, 2004; Whittlesea, 1993) or semantically coherent sequences (Topolinski & Strack, 2009b).

How perceptual and conceptual fluency interact is not fully understood. Only few studies have addressed the relationship between effects of perceptual and conceptual fluency (see Lanska, Olds, & Westerman, 2014; or Lee & Labroo, 2004, for two notable exceptions). In the realm of recognition memory, Lanska et al. (2014) showed that manipulations of both perceptual and conceptual fluency influenced recognition memory to a similar extent (see also Alter & Oppenheimer, 2009b; Lee & Labroo, 2004). When focusing on perceptual features during encoding, the effects of perceptual fluency could be accentuated, whereas when focusing on conceptual features conceptual fluency could be accentuated.

Open questions addressed in this thesis

First, in the formation of a fluency experience, it is not yet clear how ease-of-processing is evaluated. Specifically, it is not clear whether experiences of fluency require variations in ease-of-processing within a stimulus set (as a reference) or whether ease-of-processing can be evaluated in an absolute manner (as for example pitch, Takeuchi & Hulse, 1993). We contributed by testing whether both experiences of fluency and evaluations of liking are differentially affected by manipulating ease-of-processing between-participants or within-participants (publication: **Everything's relative? Relative differences in processing fluency and the effects on liking**).

Second, the nature and impact of the experience of fluency, i.e. the subjective feelings of fluency, is not fully understood. In detail, we addressed the questions:

- Do participants have a conscious subjective feeling of fluency (publication: **It felt fluent, and I liked it: Subjective feeling of fluency rather than objective fluency determines liking**)?

- Does a direct manipulation of the feelings of fluency indeed affect evaluations (publication: **Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation**)?
- What is the affective quality of these feelings of fluency (publication: **Exploring the subjective feeling of fluency**)?

Third, we addressed the fact that processing fluency research has been mainly conducted with simple stimuli, which do not afford elaborate aesthetic judgments. Using ambiguous artworks (publication: **Image Ambiguity and Fluency**) and faces varying in attractiveness (publication: **It felt fluent but I did not like it – Fluency effects in faces vs. patterns**) we tested whether the main tenets of processing fluency still hold when the material is more elaborate and more ecologically relevant for evaluations of liking/disliking. Thus, throughout this thesis, it was assessed whether different classes of objects (faces, patterns, artworks, or simple line drawings) show similar fluency effects. Especially, in the last contribution we directly compared faces and patterns in a matched design.

1) Everything's relative? Relative differences in processing fluency and the effects on liking

Introduction

The present paper is currently under peer-review in PLoS ONE. Parts of the data have been presented at the 18th Meeting of the European Society for Cognitive Psychology (ESCP) in Budapest, and at the 36th European Conference on Visual Perception (ECVP) in Bremen.

In two experiments we addressed the questions: How do individuals arrive at a feeling of fluency? How do individuals evaluate how easily something is processed? In general, there are two major possibilities (see also Whittlesea & Leboe, 2003): (a) individuals evaluate the ease-of-processing of a stimulus in comparison to an internal reference frame or expectation (Whittlesea & Williams, 2000, 2001a, 2001b). In other words, individuals have the ability to evaluate how easy a stimulus was processed without any external reference (similar to evaluations of pitch, Takeuchi & Hulse, 1993). On the other hand, (b) individuals may evaluate the ease-of-processing of a stimulus *relative* to previous experiences of ease-of-processing. In a typical experiment, the most salient previous experiences are probably previous trials. Thus, participants might evaluate the ease-of-processing of a current stimulus relative to the previously presented stimuli (see also J. Hansen, Dechêne, & Wänke, 2008), thereby producing effect.

To pit these possibilities against each other we manipulated ease-of-processing either within-participants or between-participants. In the within-participants condition, participants could draw relative comparisons among the stimuli varying in ease-of-processing. In the between-participants condition, no relative comparisons were possible with regard to the manipulation. Therefore, participants could not rely on relative differences among the stimuli.

Previous studies have predominantly applied within-participant designs when testing effects of ease-of-processing manipulations on evaluations. We thus tested whether the type of manipulation (within or between) influences evaluations of liking (e.g., Reber et al., 1998). Furthermore, to capture another facet of fluency, we measured how certain participants were regarding their liking evaluations. As higher ease-of-processing indicates successful recognition and error-free processing (Reber, Schwarz, et al., 2004), certainty evaluations should increase (see also Alter et al., 2007; Simmons & Nelson, 2006).

To determine how relative or absolute reference frames contribute to the feeling of fluency, ease-of-processing was manipulated once within- and once between-participants. In both experiments we applied two manipulations of ease-of-processing: variations in presentation duration (100,200,300, 400 ms) and variations in visual clarity (half of the stimuli were overlaid with white noise). Using two manipulations of ease-of-processing enabled us to also study the interaction of multiple sources of the feeling of fluency on evaluations. As shown in Figure 1 in the contribution (p. 39), in Experiment 1 the presentation duration was manipulated within-participants and visual clarity was manipulated between-participants. While all participants saw stimuli at different presentation durations, half of the participants saw stimuli overlaid with white noise, whereas the other half saw stimuli without noise. In Experiment 2 both manipulations were within-participants. Thus, all participants saw stimuli with and without noise at different presentation durations (fully crossed).

If ease-of-processing is evaluated in comparison to an internal reference, we would expect to observe feelings of fluency, and consequently higher liking and certainty, regardless of whether the manipulation was within- or between-participants. If on the other hand ease-of-processing is evaluated relatively to other stimuli, we would expect to observe feelings of fluency, higher liking, and certainty *only* in the within-participants condition.

Original Manuscript**RELATIVE DIFFERENCES IN FLUENCY AND LIKING**

Everything's relative? Relative differences in processing fluency and the effects on liking

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Abstract

Explanations of aesthetic pleasure based on processing fluency have shown that ease-of-processing fosters liking. What is less clear, however, is how processing fluency arises. Does it arise from a relative comparison among the stimuli presented in the experiment? Or does it arise from a comparison to an internal reference or standard? To address these questions, we conducted two experiments in which two ease-of-processing manipulations were applied: either (1) within-participants, where relative comparisons among stimuli varying in processing ease were possible, or (2) between-participants, where no relative comparisons were possible. In total, 97 participants viewed simple line drawings with high or low visual clarity, presented at four different presentation durations, and rated for felt fluency, liking, and certainty. Our results show that the manipulation of visual clarity led to differences in felt fluency and certainty regardless of being manipulated within- or between-participants. However, liking ratings were only affected when ease-of-processing was manipulated within-participants. Thus, feelings of fluency do not depend on the nature of the reference. On the other hand, participants liked fluent stimuli more only when there were other stimuli varying in ease-of-processing. Thus, relative differences in fluency seem to be crucial for liking judgments.

Introduction

The relationship between ease-of-processing and liking is an important issue in theories of processing fluency: the easier a stimulus can be processed the more it is liked [1]. The theory suggests that processing ease—i.e. processing fluency—signals a positive state of affairs, absence of threat, and safety, which are hedonically positive [2]. This positivity is then interpreted as a positive reaction towards the stimulus, resulting in liking. Various studies have shown that higher ease-of-processing indeed is associated with higher liking judgments (see [3], for a review).

What is less clear, however, is how processing fluency arises. Does it arise from a comparison between the experienced processing ease of a stimulus and processing ease of previously seen stimuli? That is, do participants infer processing ease in a relative manner? This would be in accordance with studies showing that evaluations depend on relative differences among stimuli of a given stimulus set [4-6]. Alternatively, one could assume that individuals experience processing fluency of a stimulus with regard to an internal reference or standard in an absolute manner—as for example shown in studies of absolute pitch [7]. In two experiments, we shed light on these questions by comparing effects of ease-of-processing manipulated between-participants or within-participants. This allowed us to study whether the presence of an external reference frame in terms of more or less fluent trials—in a within-participants design—is necessary for processing fluency and for fluency effects on evaluations, such as liking judgments. The experiments compare the two alternatives, and also provide evidence regarding appropriate future research designs for study of fluency-liking effects.

Studying the source of processing fluency is in the tradition of the longstanding question whether a reaction to a stimulus is due to stimulus properties (objectivist, bottom-up), perceiver properties (subjectivist, top-down) or an interaction between those two (interactionist, see [1]). In their seminal article about processing fluency and aesthetic pleasure, Reber and colleagues favour an interactionist account [1]. Pleasure is derived from higher ease-of-processing which arises from an interaction between a perceiver and a stimulus. How this interaction works in detail, however, is not fully understood.

One possible explanation for the origin of processing fluency can be derived from another theory explaining the concept: the discrepancy-attribution hypothesis [8-10]. This hypothesis addresses the effects of processing fluency on feelings of familiarity. The main tenet is that individuals are able to monitor the coherence of their processing. That is, when

the experience of processing ease is higher than expected, this discrepancy triggers an attribution process [9]. When ease is attributed to prior experience, feelings of familiarity can arise. Importantly, for processing ease, this model suggests an internal reference frame of how easy something can be processed. This reference frame is then used to compare the local processing experience. The exact manner of how this reference frame is implemented in the cognitive system has not been specified.

In memory research, in which the discrepancy-attribution hypotheses originates, an insight into the ease of retrieval of memory traces—how easy a stimulus comes to mind by comparison to an internal reference frame—seems plausible (see [11]). However, in the case of perceptual fluency [12], ease-of-processing stems from sources such as variations in visual clarity, contrast, or presentation duration. In these cases, it seems more plausible that processing fluency arises through comparisons with an external reference frame. Fluency of a stimulus is higher because it is clearer, has a higher contrast or is perceived longer; but only in relation to other stimuli in the set. This means that the ease in processing a present stimulus is compared with the ease in processing the previous stimuli. Analysing order effects of fluency, Hansen, Dechêne and Wänke ([13], see also [14]) showed that effects of ease-of-processing on truth judgments are strongest in trials when the ease in a trial was discrepant with the previous trial. This suggests that ease-of-processing might be determined relative to previous experiences of ease. However, especially for liking judgments, the importance of other stimuli as a reference for ease-of-processing still remains to be systematically tested.

One possible method to test whether processing fluency is inferred in a relative or absolute manner is to employ a fluency manipulation both within a between-participants and a within-participants design. In a between-participants design, where one group of participants receives easy-to-process stimuli while the other group receives hard-to-process stimuli, relative comparisons would not be possible. However, processing fluency still could be

inferred with regard to an internal reference frame. That is, we may still determine whether the processing ease of the stimulus is different from ones' expectations [8-10]. It is an open question whether such fluency effects due to an internal reference frame (in between-participants manipulations of ease-of-processing) are similar to fluency effects due to an external reference frame (in within-participants manipulations).

To our knowledge, in processing fluency research only one study by Lanska, Olds, and Westerman [15] used both between-participants and within-participants manipulations of processing ease. Though the experiments were designed to compare effects of perceptual and conceptual fluency on recognition judgments, in Experiment 1a fluency was manipulated between-participants and in Experiment 1b fluency was manipulated within-participants. The effects of both perceptual and conceptual fluency on recognition judgments were similar regardless whether these were tested between- or within-participants. Thus, in the between-participants design used in this study, participants presumably employed an internal reference frame, which led to a consistent experience of fluency. This is also in line with the discrepancy-attribution hypothesis, which predicts use of an internal reference for feelings of familiarity. However, for perceptual fluency manipulations and for liking judgments, this may not be the case.

Thus, given the sparse empirical data, we conducted two experiments that differed in regards to whether an ease-of-processing manipulation varied between-participants or within-participants. To manipulate ease-of-processing, simple line drawings were either presented with overlaid random noise (low visual clarity and low ease-of-processing) or without random noise (high visual clarity, high ease-of-processing). In addition to this manipulation, we presented the stimuli at different presentation durations (within-participants, see [12, 16, 17]). Therefore, in Experiment 1, visual clarity served as a between-participants manipulation of ease-of-processing with an additional within-participants manipulation of ease-of-processing

through presentation duration. In Experiment 2, both visual clarity and presentation duration were manipulated within-participants (see Table 1).

Table 1. Experimental design of Experiments 1 and 2.

	Ease-of-processing manipulation	
	Presentation duration (100, 200, 300, 400 ms)	Visual Clarity (noise, no-noise)
Experiment 1 (n = 64)	Within-participants	Between-participants n = 32 Noise n = 32 No-Noise
Experiment 2 (n = 33)	Within-participants	Within-participants

This procedure was chosen because using two manipulations of perceptual fluency allows us to study joint effects on ease-of-processing. This also more closely resembles our everyday experiences where sources of fluency are manifold (e.g., presentation duration, visual clarity, and repetition, see [18]).

In both experiments, we tested the effects of the manipulations on three main variables: felt fluency, liking, and certainty. Measures of felt fluency indicated whether both manipulations indeed lead to a subjective experience of fluency [19, 20]. It is an ongoing debate whether processing fluency itself can be consciously reported. Reber, Fazendeiro, and Winkielman [21] argue that processing fluency “is typically experienced at the periphery of the conscious awareness, resulting in a vague or ‘fringe’ experience of ease” (p. 3). However, recent findings indicate that participants do have conscious insight into their ease-of-processing [16, 19, 20]. When higher processing ease is only reflected in higher liking [21], or in shorter reaction times ([19], but see [22]), then our manipulations might not be reflected in felt fluency. However, irrespective of conscious insight into processing ease, higher ease-of-

processing should be reflected in higher liking ratings. Therefore, we tested both felt fluency and liking. With the additional measure of certainty—how certain are participants about their liking decision— we tried to capture another facet of fluency. According to Reber, Schwarz, and Winkielman, higher ease-of-processing signals “progress toward successful recognition of the stimulus, error-free processing, or the availability of appropriate knowledge structures to interpret the stimulus” ([1], p.366, see also [2]). If fluency indicates successful recognition or error-free processing, then participants might be more confident about their perception, resulting in higher certainty judgments (see also [23, 24]).

Experiment 1

Method

Ethics Statement

Both experiments were conducted in accordance with the Declaration of Helsinki (revised, 1983) and the guidelines of the Faculty of Psychology, University of Vienna. According to the Austrian Universities Act 2002 (UG2002) which was active at the time the study was carried out, only medical universities were required to appoint ethics committees for clinical testing, application of medical methods and applied medical research. Therefore, no ethical approval was sought for the experiments. All participants provided written informed consent prior to their participation. Participants were informed that participation and data collection was fully anonymous and that they could withdraw at any time during the experiment without any further consequences. Each participant received an anonymized code upon beginning the study which was used to identify both consent form and the results sheet containing main study results. The pre-screening for eyesight and color vision was administered by the experimenter (MF), with results also recorded on a separate anonymized sheet. Consent forms were stored separately from the data sheet, with the former (physical paper) held in a locked cabinet and the latter (digital records of study answers/reaction times)

stored in a password protected server. Thus, only the administering researcher (MF) had access to both age/names and study results. Co-authors had access to the anonymized results only. The consent forms and codes were kept in order to ensure the rights of the participants to later inspect their own data or to have their data deleted upon request.

Participants

Sixty-four volunteers (48 women) participated in Experiment 1. Mean age was 22.5 years ($SD = 4.1$, age range = 18–44). In a pre-screening we ensured that all participants had normal vision.

Stimuli

We selected 96 black-and-white line pictures (image size: 3.2×2.3 in., or $6.79^\circ \times 4.75^\circ$ of visual angle at a viewing distance of approx. 27.56 in.) from the picture set of Rossion and Pourtois [25]. This set comprises simple drawings of everyday objects, such as an anchor, dog, spoon etc. For the condition with low visual clarity, and hence low ease-of-processing, we added 60% Gaussian noise to the original picture (see also [12]). To assure that visual processing did not outlast the presentation duration, a masking stimulus consisting solely of 60% Gaussian noise was created (see Fig. 1).

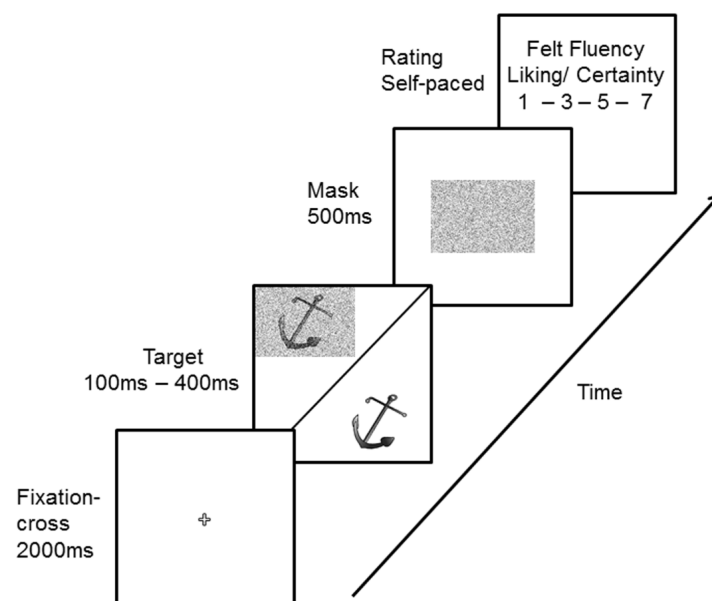


Fig. 1. Trial sequence with respective presentation durations to the left. In Experiment 1, half of the participants were presented with targets with Gaussian noise, the other half of the participants were presented with targets without Gaussian noise. In Experiment 2, participants were presented with both types of targets (with and without Gaussian noise).

Design and Procedure

Half of the participants ($n = 32$) viewed the original images without any image manipulation (*no-noise* condition, with high visual clarity/ease-of-processing). The other half viewed the images with 60% Gaussian noise added (*noise* condition, with low visual clarity/ease-of-processing). The experiment consisted of two blocks: (1) one in which all stimuli were rated for felt fluency, and (2) one in which they were rated for liking and certainty. In both blocks, ease-of-processing was additionally manipulated by varying the presentation duration in 100 ms steps between 100 and 400 ms [12, 16]. To avoid repetition of the images, and in order to reduce effects when felt fluency and liking are recognized as belonging together [26], felt fluency was rated in one block and liking as well as certainty in another block.

The assignment of participants to the noise or no-noise condition was pseudo-randomized upon their arrival in the lab. For each participant the four different presentation durations (100, 200, 300, or 400 ms) were randomly assigned to the 96 stimuli. The only constraint involved assuring that each of the presentation durations occurred equally often (i.e., 24 times). Consequently, for each participant each stimulus was presented in only one of the four presentation durations. The order of the rating blocks (felt fluency or liking/certainty) was counterbalanced across participants. In the second rating block, the stimuli were repeated with the same presentation duration as in the first rating block. The order of the stimuli, however, was randomized.

In order to conceal the link between the felt fluency block and the liking/certainty block, the experiment started with an instruction phase in which the participants were told that there were two independent blocks of ratings to be made. After this instruction, participants were familiarized with the task in four practice trials. Each trial started with a fixation cross for 2 s, followed by the target image for 100, 200, 300 or 400 ms. A subsequent 500 ms noise mask limited visual processing of the target. Finally, depending on block order, the participants gave felt fluency (“How easy was the perception of the presented stimulus?”) or liking (“How much do you like the picture?”) and certainty (“How certain are you in your judgment?”) ratings. All ratings were given on a Likert-type scale. For the felt fluency rating the scale ranged from 1 (*very easy*) to 7 (*very hard*). For the liking and certainty ratings the scale ranged from 1 (*not at all/very uncertain*) to 7 (*very much/very certain*). For data analysis, the felt fluency rating scale was inverted to simplify interpretation. Higher ratings consequently represent higher felt fluency, liking or certainty. Within blocks, presentation order of stimuli and different durations were randomized. The experiment was run with E-Prime 2.0 [27] and presented on a 19” display at a resolution of 1,280 × 1,024 pixels and a refresh rate of 60 Hz. After completing the experiment, the participants filled out post-questionnaires regarding the assumed purpose of the experiment. Finally, participants were thoroughly debriefed and thanked for their participation.

Results and Discussion

To test the effect of both ease-of-processing manipulations on the dependent variables, we ran three mixed factors analyses of variance (ANOVA): one for felt fluency, one for liking, and one for certainty. For all three ANOVAs the between-participants factor was *stimulus condition* (noise or no-noise) and the within-participants factor was *presentation duration* (100, 200, 300, or 400 ms). In all analyses the level of statistical significance was set at $p < .05$. In cases where sphericity assumption was violated, Greenhouse-Geisser correction

was applied. For analyses of the different presentation durations, we performed linear trend analyses, given our hypothesis that ratings of felt fluency, liking, and certainty should linearly increase with longer presentation durations. To further investigate interaction effects we either performed separate ANOVAs for the two stimulus conditions or multiple pairwise comparisons with Bonferroni correction.

Felt fluency

Testing whether both manipulations of ease-of-processing yielded differences in the experience of fluency, ANOVA showed a main effect of stimulus condition, $F(1, 62) = 15.43$, $p < .001$, $\eta_p^2 = .20$, and a main effect of presentation duration, $F(2.4, 150.8) = 37.47$, $p < .001$, $\eta_p^2 = .38$. However no interaction was detected, $F(2.4, 150.8) = 1.23$, $p = .300$, $\eta_p^2 = .02$. Felt fluency was higher in the stimulus condition without noise than in the stimulus condition with noise ($p < .001$, see Table 2 and Fig. 2). Linear trend analysis showed that felt fluency significantly increased with presentation duration, $F(1, 62) = 70.54$, $p < .001$, $\eta_p^2 = .53$. These results showed that differences in ease-of-processing both between and within the participants were reflected in differences in felt fluency. Thus, in the case of visual clarity no external reference was needed for fluency to be experienced. In line with the discrepancy attribution hypothesis [9, 10], participants may have relied on an internal reference frame. The analysis for liking ratings tested whether these differences in felt fluency translated into differences in liking, as suggested by processing fluency approaches to aesthetic pleasure [1].

Table 2. Means and standard deviations (in parentheses) for felt fluency, liking, and certainty in Experiments 1 and 2.

		Experiment 1			
		Ease-of-processing			
Dimension	Condition	100ms	200ms	300ms	400ms
Felt	Noise	5.01 (1.05)	5.19 (1.07)	5.46 (1.10)	5.60 (0.98)
Fluency	No-Noise	5.85 (0.81)	6.17 (0.74)	6.30 (0.72)	6.37 (0.77)

Liking	Noise	3.80 (0.72)	3.85 (0.79)	4.07 (0.74)	3.96 (0.71)
	No-Noise	3.62 (0.84)	3.86 (0.77)	3.73 (0.86)	3.85 (0.71)
Certainty	Noise	5.21 (0.90)	5.37 (0.84)	5.44 (0.83)	5.42 (0.83)
	No-Noise	5.54 (0.94)	5.77 (0.77)	5.76 (0.68)	5.86 (0.72)

Experiment 2

Dimension	Condition	Ease-of-processing			
		100ms	200ms	300ms	400ms
Felt	Noise	4.97 (1.37)	5.19 (1.41)	5.36 (1.31)	5.29 (1.28)
Fluency	No-Noise	6.54 (0.58)	6.74 (0.39)	6.78 (0.36)	6.82 (0.35)
Liking	Noise	3.12 (1.20)	3.12 (1.51)	3.33 (1.19)	3.34 (1.27)
	No-Noise	4.17 (1.51)	4.16 (1.50)	4.30 (1.60)	4.39 (1.63)
Certainty	Noise	5.93 (1.04)	5.92 (1.06)	6.12 (0.90)	6.15 (0.92)
	No-Noise	6.19 (0.97)	6.36 (0.71)	6.38 (0.76)	6.38 (0.80)

Means are separated by ease-of-processing (presentation duration of 100, 200, 300, or 400 ms), by stimulus condition (noise or no-noise).

Experiment 1

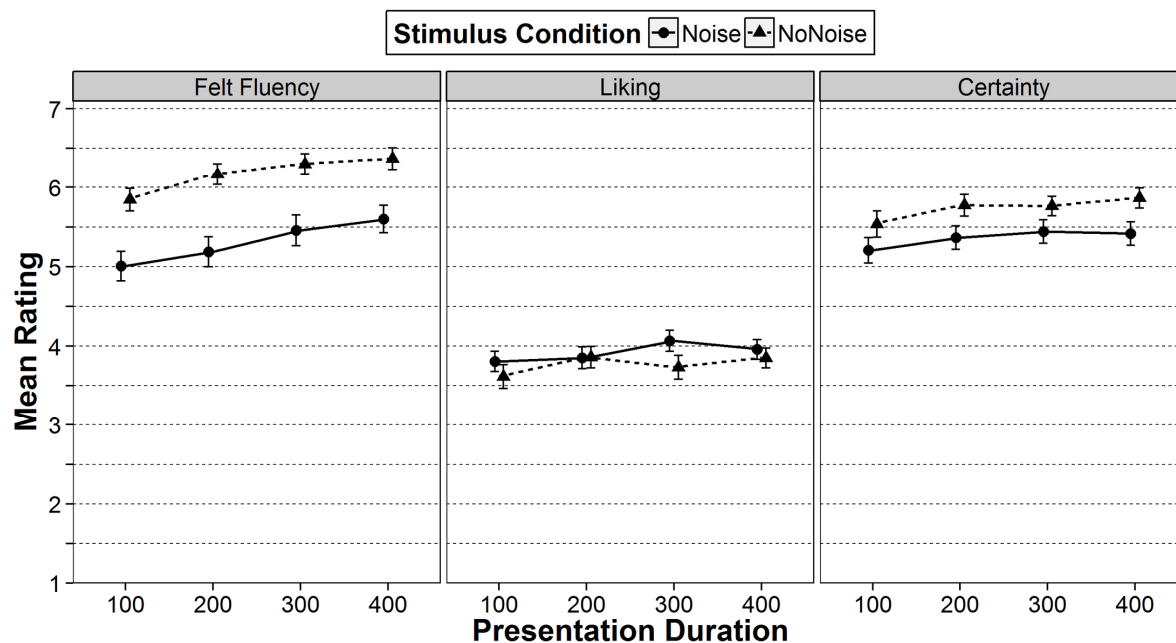


Fig. 2. Mean ratings of felt fluency, liking, and certainty in Experiment 1. Means are separated by ease-of-processing (presentation duration of 100, 200, 300, or 400 ms) and by stimulus condition (noise or no-noise). The error bars represent $\pm$ one standard error of the mean.

Liking

For ratings of liking the ANOVA showed no significant main effect of stimulus condition, $F(1, 62) = 0.75$, $p = .389$, $\eta_p^2 = .01$, but a significant main effect of the within-participants factor presentation duration, $F(3, 186) = 5.07$, $p = .002$, $\eta_p^2 = .08$. This was also qualified by a significant interaction between stimulus condition and presentation duration, $F(3, 186) = 3.15$, $p = .026$, $\eta_p^2 = .05$. The interaction was mainly due to the fact that for the group with noise, the linear trend for higher liking with increasing presentation duration was stronger, $F(1, 31) = 5.12$, $p = .031$, $\eta_p^2 = .14$, than for the group without noise, $F(1, 31) = 4.09$, $p = .052$, $\eta_p^2 = .12$. Taken together, in both stimulus conditions, liking ratings tended to be higher at longer durations.

Separate comparisons between the stimulus conditions for the four presentation durations yielded no significant differences ($ps > .101$). As evident from Fig. 2 (left column), the mean liking ratings in the no-noise condition with high visual clarity—where ease-of-processing was higher—tended to be even lower compared to the noise condition with low visual clarity. This indicated that higher ease-of-processing, when varied between-participants, was not accompanied by higher liking ratings. This finding however could not be attributed to lack of felt fluency difference between the two stimulus conditions. As shown above, felt fluency was influenced by the between-participants manipulation of ease-of-processing. Nonetheless, for the between-participants factor, the differences in felt fluency did not translate into differences in liking. It rather appeared that only the experience of a *relative* higher fluency of longer presented stimuli—within-participants—results in higher liking [1].

Certainty

Following the processing fluency theories, when a stimulus can be processed fluently participants should also be more certain about their evaluations [23, 24]. Thus, participants rated how certain they were about their liking evaluations. ANOVA with certainty ratings as a dependent variable showed a trend of stimulus condition, $F(1, 62) = 3.71, p = .059, \eta_p^2 = .06$, as well as a significant main effect of presentation duration, $F(3, 186) = 12.10, p < .001, \eta_p^2 = .16$, but no interaction, $F(3, 186) = 0.80, p = .495, \eta_p^2 = .01$. As shown in Fig. 2, participants in the stimulus condition without noise tended to be more certain than in the condition with noise. Furthermore, certainty ratings increased with presentation duration, $F(1, 62) = 25.51, p < .001, \eta_p^2 = .29$. Certainty ratings, therefore, mirrored effects of felt fluency (see also [23, 24, 28]).

Order effects

Repeating the stimuli in the two blocks posed the possibility of block order effects. For all three dimensions (felt fluency, liking, and certainty) mixed-design ANOVAs with *block order* and *stimulus condition* as between-participants factors and *presentation duration* as within-participants factor were performed. For the sake of parsimony only main effects of block order and interactions including block order are reported. For felt fluency, the ANOVA showed a trend for an interaction between block order and presentation duration, $F(2.48, 148.52) = 2.40, p = .082, \eta_p^2 = .04$. To further inspect the interaction, we performed two ANOVAs separately for the two block orders. As indicated by the effect sizes, there was a stronger linear trend for presentation duration, when felt fluency was tested in the second block, $F(1, 30) = 59.494, p < .001, \eta_p^2 = .67$, compared to when felt fluency was tested in the first block, $F(1, 30) = 20.76, p < .001, \eta_p^2 = .41$. Importantly, this interaction does not qualify the previous findings. For liking, no effect was significant ($ps > .157$). For certainty, an

ANOVA showed a significant main effect of block order, $F(1, 60) = 4.45$, $p = .039$, $\eta_p^2 = .07$.

Certainty ratings were higher when tested in the second block.

Experiment 2

The results from Experiment 1 indicate that both relative and absolute differences of ease-of-processing are subjectively felt as fluent. Furthermore, these differences were also reflected in certainty ratings. That is higher ease-of-processing accompanied higher certainty in judgments. However, only the differences in relative fluency (i.e. differences in presentation duration) also revealed differences in liking. In both stimulus conditions, longer presentation durations were associated with higher liking. However, images presented without noise were not generally liked more. One possible reason might be that differences in visual clarity (i.e. presence or absence of noise) in general do not translate into differences in liking. This however seems unlikely, as visual clarity in general is associated with higher liking [12, 29] and as differences in stimulus clarity were associated with differences in felt fluency. Nonetheless, to rule out this possibility and to explicitly test whether differences in visual clarity translate into differences in liking when visual clarity is relatively higher, we conducted a similar experiment with the added manipulation of both presentation duration as well as visual clarity within-participants.

Method

Participants

Thirty-three volunteers (17 female) participated in Experiment 2. Mean age was 30.6 years ($SD = 7.0$, age range = 21–49). In a pre-screening we ensured that all participants had normal vision. None of the participants took part in Experiment 1.

Stimuli

The same stimuli as in Experiment 1 were used.

Design and Procedure

The only difference from Experiment 1 was that stimuli with and without noise were presented within participants. That is, participants were presented with stimuli both with high and low visual clarity. For each participant the four different presentation durations (100, 200, 300, or 400 ms) and the two stimulus conditions (noise or no-noise) were randomly assigned to the 96 stimuli. Each of the presentation durations in combination with the two stimulus conditions were however presented equally often (12 times). Consequently, for each participant, each stimulus was presented in only one of the four presentation durations and either with or without noise. All other aspects were identical to Experiment 1.

Results and Discussion

We ran three repeated measures analyses of variance (ANOVA): one for felt fluency, one for liking, and one for certainty. For all three ANOVAs, the within-participants factors were *stimulus condition* (noise or no-noise) and *presentation duration* (100, 200, 300, or 400 ms).

Felt fluency

The ANOVA showed a main effect of stimulus condition, $F(1, 32) = 64.99, p < .001$, $\eta_p^2 = .67$, a main effect of presentation duration, $F(3, 96) = 11.74, p < .001$, $\eta_p^2 = .27$, but no interaction, $F(3, 96) = 0.56, p = .641$, $\eta_p^2 = .02$. Felt fluency significantly increased with presentation duration, $F(1, 32) = 20.44, p < .001$, $\eta_p^2 = .39$ (see also Fig. 3). Felt fluency was also rated higher for stimuli without noise than for stimuli with noise (see Table 2 and Fig. 3). This result showed that differences in ease-of-processing of both manipulations were reflected in differences in felt fluency. Manipulations of presentation duration and stimulus noise were also additive. As indicated by the high means for the stimuli without noise (dashed line in the left column in Fig. 3), the ratings of felt fluency appeared to reach a ceiling. As indicated by the effect sizes, the ease-of-processing differences through visual clarity (noise or no-noise)

led to stronger differences in felt fluency than the ease-of-processing differences through presentation duration. Thus, when both manipulations were presented within-participants, visual clarity was a more powerful manipulation of ease-of-processing.

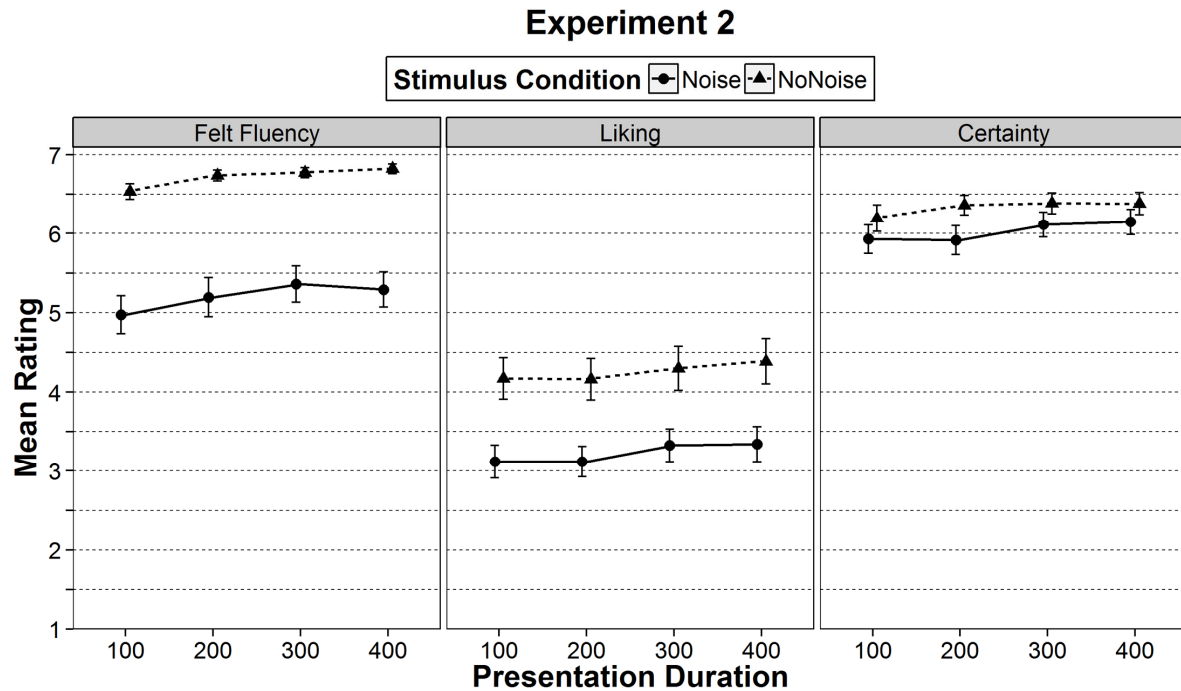


Fig. 3. Mean ratings of felt fluency, liking, and certainty in Experiment 2. Means are separated by ease-of-processing (presentation duration of 100, 200, 300, or 400 ms) and by stimulus condition (noise or no-noise). The error bars represent $\pm$ one standard error of the mean.

Liking

For ratings of liking, the ANOVA showed a significant main effect of stimulus condition, $F(1, 32) = 14.15, p < .001, \eta_p^2 = .31$, a significant main effect of presentation duration, $F(3, 96) = 3.72, p = .014, \eta_p^2 = .10$, but no significant interaction between stimulus condition and presentation duration, $F(3, 96) = 0.14, p = .939, \eta_p^2 < .01$. As indicated in Fig. 3, stimuli without noise, which are easier to perceive, were liked more. Liking also significantly increased with presentation duration, $F(1, 32) = 8.61, p = .006, \eta_p^2 = .21$. In

contrast to Experiment 1, both manipulations of fluency exerted their influence on liking. As indicated by the effect sizes, the manipulation of visual clarity did so more strongly ($\eta_p^2 = .31$) than the manipulation of presentation duration ($\eta_p^2 = .10$). Taken together, this finding strengthens the argument that the experience of a relative higher fluency—within-participants—is necessary for increases in liking due to ease-of-processing.

Certainty

An ANOVA on certainty ratings showed a significant main effect of stimulus condition, $F(1, 32) = 7.21, p = .011, \eta_p^2 = .18$, a significant main effect of presentation duration, $F(2.4, 77.6) = 7.53, p < .001, \eta_p^2 = .19$, but no interaction, $F(1.8, 56.5) = 1.25, p = .291, \eta_p^2 = .04$. As indicated in Fig. 3, participants in the stimulus condition without noise were more certain than in the condition with noise ($p = .011$). Furthermore, certainty ratings increased with presentation duration, $F(1, 32) = 15.74, p < .001, \eta_p^2 = .33$. The similarity between certainty ratings and felt fluency ratings indicated that certainty might indeed be an alternative measure of processing fluency.

Order effects

For felt fluency, a mixed-design ANOVA with *block order* as a between-participants factor and *stimulus condition* and *presentation duration* as within-participants factors showed a significant main effect of block order, $F(1, 31) = 5.21, p = .029, \eta_p^2 = .14$, qualified by a significant interaction between block order and stimulus condition, $F(1, 31) = 4.28, p = .047, \eta_p^2 = .12$. There also was a trend for an interaction between block order and presentation duration, $F(2.42, 75.11) = 2.41, p = .086, \eta_p^2 = .07$. When felt fluency was tested first, ratings were higher than when tested second. The interaction effects are mainly due to the fact that the differences between first and second block were only significant in the noise condition ($p = .031$; no-noise, $p = .097$). The trend for the interaction with presentation duration was due to the difference between first and second block not being significant in the 300 ms condition (p

= .078, all other $ps < .048$). These interactions do not qualify the previous findings. For liking and certainty no effect, including block order, was significant ($ps > .146$).

General Discussion

In two experiments we tested whether an external reference frame is needed for fluency effects, or whether fluency also arises without this. Our results show that manipulations of ease-of-processing lead to higher feelings of fluency and higher certainty, regardless of whether other stimuli vary in ease-of-processing or not. However, effects of higher ease-of-processing on liking were only found when participants could experience relative differences in ease-of-processing. In the following we consider this, on the surface rather inconsistent, finding.

For felt fluency effects of within-participants manipulations (Experiment 1: presentation duration, Experiment 2: visual clarity, presentation duration), our results are in line with previous research on processing fluency (e.g., [12, 16]). Thus, the explanation is straightforward: Participants could compare the felt fluency in each trial with the felt fluency of other trials. If a stimulus was presented longer than another stimulus, it felt more fluent. This is quite consistently shown in the ratings (see left columns in Figs. 2 and 3). For the manipulation of visual clarity in Experiment 2 the same logic can be applied. If a stimulus was higher in visual clarity than another stimulus, it felt more fluent.

However, felt fluency ratings for visual clarity also differed in Experiment 1, where participants could not perform a comparison between high and low visual clarity. These findings, importantly, show that feelings of felt fluency can arise without experiencing relative differences in ease-of-processing among stimuli. This is in line with Whittlesea and Williams [9, 10], who suggest that fluency can also arise from a comparison between experienced and expected ease. This further suggests that for manipulations of perceptual

fluency individuals can apply an internal reference frame regarding how easy something can be processed. To our knowledge this is the first time an external and an internal reference frame in processing fluency have been directly compared.

Though previous experiments have shown that differences in ease-of-processing can be reported by participants [16, 19, 20], one might still argue that ratings of felt fluency are an improper measure of ease-of-processing. We thus measured certainty as an additional measure of ease-of-processing [23, 24]. The results for certainty indicated that easier to process stimuli lead to a higher certainty in liking ratings. Thus, higher ease-of-processing might accompany participants also being more confident that they have successfully perceived the stimulus itself [2, 23, 24]. Consequently, this confidence might have been used as a cue for the certainty in liking ratings.

Taken together, manipulating the ease-of-processing through visual clarity led to differences in felt fluency in both experiments. These results indicate that felt fluency can be inferred relative to an external reference (i.e., compared to other stimuli) and relative to an internal reference (i.e., an internal standard). Whether these feelings of fluency stemming from an external or internal reference reflect a similar quality or a similar internal process cannot be inferred from our results. However, according to Alter and Oppenheimer [3] such a distinction might not be important, as fluency can arise from a variety of sources but may result in very similar outcomes. This is also shown in our study. Regardless of the context of manipulation—between or within— or the type of manipulation—visual clarity or presentation duration—certainty and felt fluency ratings increased with ease-of-processing.

Liking ratings, however, were differentially affected by the ease-of-processing manipulations. At this point we can mainly rule out explanations of why liking judgments were not affected when variations in ease-of-processing due to visual clarity were manipulated between-participants (Experiment 1). First, it can be ruled out that the between-

participants manipulation in visual clarity failed. The effects on felt fluency and certainty are indicative of its success.

Second, discounting of fluency—a concept often discussed in processing fluency research [26]—can also be ruled out. Discounting means that when participants become aware of the manipulation of ease-of-processing, they disregard feelings of fluency as a source for their liking ratings. Accordingly, within-participants compared to between-participants manipulations should be more prone to discounting effects as manipulations are more apparent in the within-participants condition. Thus, particularly liking ratings in the within-participants manipulations should have suffered from discounting. This was not the case. Furthermore, for ratings of liking the awareness of the manipulation was certainly higher in participants who received the liking block second. Following the discounting argument these participants should show weaker effects of ease-of-processing on liking. As indicated by the absence of any effect of block order on liking in Experiments 1 and 2, this was not the case. Taken together we could find no evidence for discounting in our experiments.

One possibility why felt fluency did not affect liking in the between-participants condition is that it was not regarded as a valid source for liking ratings. In the absence of an external comparison for visual clarity, the salience of the fluency feeling may not have been high enough to be applied as a source of information (see also [30]). The inspection of the effect sizes supports this hypothesis. In Experiment 1, effect sizes indicate a stronger felt fluency effect for presentation duration (within-participants) compared to visual clarity (between-participants). Thus, the presentation duration manipulation might have been more salient. In Experiment 2 however, effect sizes indicated a stronger felt fluency effect for visual clarity (within-participants) compared to presentation duration (within-participants). This difference in felt fluency strength is also reflected in a stronger effect size in the liking ratings for visual clarity. Thus in Experiment 1, not visual clarity [29] but other features of the

stimuli, such as roundness [31], symmetry [32] or personal taste, might have governed the liking ratings. This possibility however requires further testing.

One shortcoming of the measurements should also not go unnoticed. As indicated by the high means in Experiment 2, certainty and felt fluency ratings at the highest levels of ease-of-processing nearly reached a ceiling. The means between the 300 and 400 ms presentation durations for stimuli of high visual clarity did not further increase. This indicates that felt fluency, and hence liking, may potentially not be increased indefinitely. Thus, with stimuli with high visual clarity these presentation durations do not elicit any stronger feelings of fluency or certainty. We used the variations between 100 and 400 ms because we first wanted to follow presentation durations previously used in processing fluency research [12, 16]. Second, we wanted to ensure that stimuli at the lowest levels of ease-of-processing (short presentation duration of stimuli with noise) were identifiable. Depending on stimulus category, in presentation durations below 100 ms identifiability drops considerably [33]. Thus, when presenting stimuli shorter than 100 ms, liking differences might be due to some stimuli being visible and others not. However, in our study, informal questions after the experiment did indicate that participants were able to identify the depicted objects. To allow an optimal discrimination in felt fluency among all levels of manipulations, future studies nonetheless should avoid making the processing of stimuli too easy.

To sum up, we could show that feelings of fluency arise from both within-participants and between-participants manipulations of ease-of-processing. Thus, it seems that individuals can judge felt fluency both in relation to an external reference and in relation to an internal reference. We can only speculate whether this effect will also be found with other more complex or more ecologically valid stimuli. It might be that, with faces or consumer products the effects of other types of fluency (for example previous experience or familiarity), and other sources for liking (private taste or attitudes) override the subtle effect of perceptual

fluency. What our experiments, to our knowledge for the first time, show is that effects of fluency on liking depend on the presence of relative differences in felt fluency. Participants like fluent stimuli more only when there are other stimuli varying in ease-of-processing present.

Acknowledgements

We would like to thank Marcos Nadal, Matthew Pelowski, and an anonymous reviewer for invaluable comments on earlier versions of this manuscript.

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Supporting Information

S1 File. Data-sheets from Experiments 1 and 2.

Summary & Outlook

We showed that participants reported higher feelings of fluency regardless of whether ease-of-processing was manipulated within- or between-participants. In Experiments 1 and 2, both manipulations of ease-of-processing (presentation duration and clarity) influenced the felt fluency. This indicates that an external reference, in the form of variations in ease-of-processing among the stimuli, is not necessary for feelings of fluency (Whittlesea & Williams, 2000, 2001a, 2001b). Results regarding participant certainty in their evaluations were similar to ratings of felt fluency (Alter et al., 2007; Simmons & Nelson, 2006). Though the effects were more pronounced in the with-participants manipulations, higher ease-of-processing was associated with higher certainty in all cases.

Interestingly, the findings on liking evaluations showed that only within-participants manipulations of ease-of-processing led to higher liking. In Experiment 1, stimulus liking increased with longer presentation duration, but did not differ among the two conditions of visual clarity. Also, in Experiment 2 stimulus liking increased with longer presentation duration. Additionally, stimuli presented without noise were liked more than stimuli presented with noise. The absence of an effect from clarity in Experiment 1 cannot be due to the absence of feelings of fluency, as participants in the high visual clarity condition reported higher felt fluency than participants in the low visual clarity condition. These findings indicate that the effect of fluency on liking does depend on how the ease-of-processing is experienced. Only when stimuli in the experiment are manipulated to vary in regards to ease-of-processing, the resulting felt fluency is used as a source for liking. It may be that the between-participants manipulation of clarity was not salient enough to feature as a valid source for liking evaluations (Schwarz, 2011).

However, what the results do not show is whether participants evaluated feelings of fluency similarly in both experiments. It is possible that in the within-participants condition

participants compared the present stimulus with previously presented stimuli, while in the between-participants condition participants relied on an internal reference for evaluating felt fluency. In other words, depending on the manipulation, feelings of fluency may have originated from different processes. Following Alter and Oppenheimer (2009b), this distinction might not be crucial, as effects are similar regardless of the manipulation (see also Lanska et al., 2014, for experimental evidence). However, different processes for the formation of felt fluency in our case could explain the differential effects on liking evaluations. It might be that felt fluency, when originating from an inner reference, does not translate into liking.

Though our results suggest that participants at least in the between-participants manipulation applied an internal reference frame, we cannot distinguish whether participants used an expectation of fluency as their internal reference or whether ease-of-processing can be evaluated absolutely (as for example pitch, Takeuchi & Hulse, 1993). However, Whittlesea and Leboe (2003) could show that an absolute rating of ease-of-processing is unlikely. In a series of studies on illusions of familiarity through higher ease-of-processing, they presented evidence more in line with the idea that participants throughout the experiment form expectations of how easy something should be processed and evaluate the felt fluency on basis of these expectations (see also Kahneman & Miller, 1986).

To sum up, our experiments, to our knowledge for the first time, explicitly show that experiences of fluency arise regardless of presence or absence of other stimuli strongly varying in ease-of-processing. However, effects of fluency on liking depend on the presence of relative differences in felt fluency. Only in the presence of other stimuli varying in ease-of-processing do participants prefer fluent stimuli over less fluent stimuli.

2) It felt fluent, and I liked it: Subjective feeling of fluency rather than objective fluency determines liking

Introduction

In this paper, published in *Emotion*, we directly tested the subjective experience of fluency (felt fluency). Following the theoretical accounts of processing fluency, higher ease-of-processing is argued to be subjectively experienced as a feeling of fluency (Reber, Schwarz, et al., 2004; Unkelbach & Greifeneder, 2013). This feeling is then attributed to the stimulus and can be (mis)interpreted as a liking response to the stimulus (Unkelbach & Greifeneder, 2013).

However, previous research has not yet directly tested this feeling of fluency. It was either merely assumed that there is a feeling of fluency (Bornstein & D'Agostino, 1992, 1994), or the fluency feeling was rather indirectly addressed. Reber, Wurtz, et al. (2004), for example, showed that manipulations of perceptual fluency through contrast and font type led to higher experienced readability. It is, however, unclear whether the readability truly reflects the subjective feeling of fluency. Thus, using a more direct assessment, we asked our participants how easy the previously seen stimulus could be processed (see also Topolinski & Strack, 2009c). This question assessing the ease-of-processing should represent a more direct measure of the subjectively felt fluency.

Previous research has shown that fluency effects may vanish when participants are aware of the ease-of-processing manipulation (Bornstein & D'Agostino, 1992, 1994). To address this issue, we used two processing fluency manipulations that differed in salience. For lower salience, we used subliminal contour priming (Experiment 1, see also Exp. 1 in Reber et al., 1998; or Exp. 1 in Winkielman & Cacioppo, 2001); for higher salience, we used

different presentation durations (Experiment 2, see also Exp. 3 in Reber et al., 1998; or Exp. 2 in Winkielman & Cacioppo, 2001).

In contrast to previous research we furthermore asked for felt fluency and liking in separate blocks (Topolinski & Strack, 2009c). This allowed us to directly compare the felt fluency and the liking rating of each stimulus. Additionally, we could test whether the actual ease-of-processing manipulation or the felt fluency more strongly influenced the liking response.

It Felt Fluent, and I Liked It: Subjective Feeling of Fluency Rather Than Objective Fluency Determines Liking

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According to the processing-fluency explanation of aesthetics, more fluently processed stimuli are preferred (R. Reber, N. Schwarz, & P. Winkielman, 2004, Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review*, Vol. 8, pp. 364–382.). In this view, the subjective feeling of ease of processing is considered important, but this has not been directly tested in perceptual processing. In two experiments, we therefore objectively manipulated fluency (ease of processing) with subliminal perceptual priming (Study 1) and variations in presentation durations (Study 2). We assessed the impact of objective fluency on feelings of fluency and liking, as well as their interdependence. In line with the processing-fluency account, we found that objectively more fluent images were indeed judged as more fluent and were also liked more. Moreover, differences in liking were even stronger when data were analyzed according to felt fluency. These findings demonstrate that perceptual fluency is not only explicitly felt, it can also be reported and is an important determinant of liking.

Keywords: subjective feeling of fluency, perceptual fluency, liking, feeling of ease, ease of processing

Every day, we evaluate many things in terms of whether we like them. This occurs, for example, when we choose a soft drink, when we inspect advertisements, or when a new fashion item, artwork, or piece of music appeals to us. Even when we are not explicitly aware of why we like an object, we can judge very easily whether we like it or not. For simple spontaneous preferences, liking often seems to be based on “feeling” rather than on rational decisions or explicit insight. In the present study, we investigate how this “feeling”—or the affective component of the judgment—operates when we perceive and like a stimulus.

During stimulus perception, one moderating factor for our liking could be fluency. According to Reber, Schwarz, and Winkielman (2004), if an object can be perceived with ease, this easiness or fluency seems to increase our liking of an object (for further reviews see Alter & Oppenheimer, 2009; Winkielman, Schwarz, Fazendeiro, & Reber, 2003). Thus, according to this concept, people prefer what they experience as fluent, or what they can process fluently. For example, Reber, Winkielman, and Schwarz (1998) have shown that images made more fluent through perceptual priming, higher contrast, or longer presentation duration, were detected faster and preferred over less fluently processed images. Subsequent studies have corroborated these findings (see Reber, Schwarz, et al., 2004, for a review), and have shown that, not only objective perceptual increase of processing fluency, through priming, symmetry, or presentation duration

(Reber et al., 1998), but also conceptual manipulations, through higher semantic coherence (Topolinski & Strack, 2009a, 2009b), increase liking. But how does fluency exert its influence on liking? It is assumed that the objective fluency of a perceptual process is accompanied by a subjective experience of fluency (Koriat, 1993), of which humans are not necessarily aware (Reber, Fazendeiro, & Winkielman, 2002). Since “processing fluency is itself hedonically marked and high fluency is subjectively experienced as positive, as indicated by psychophysiological findings” (Reber, Schwarz, et al., 2004, pp. 365–366), this positive experience can subsequently be attributed to an object in the course of automatic object appraisal (Clore, 1992). Accordingly, fluency could exert its influence on our liking through the subjective feelings of ease that accompany the perceptual process.

Uncovering the nature and impact of this subjective experience, or subjective feeling of fluency (Reber et al., 2002), is a pivotal issue not only in the fluency literature (“fringes of consciousness”; Reber & Schwarz, 2002; Reber, Wurtz, & Zimmermann, 2004; Topolinski & Strack, 2009b), but also for our understanding of the role and function of consciousness in general (Craig, 2009; Damasio, 1999; Rolls, 2000), and of judgments and decision making (“cognitive feelings,” Clore, 1992; Clore et al., 2001). The term “feeling” as a subjective sensation suggests that the experience of fluency could be relatively faint, fleeting, or unspecific. That this feeling can nevertheless lead to a conscious experience of fluency was first proposed by Bornstein and D’Agostino (1992, 1994) in their perceptual fluency/attributional model. Originally proposed as an explanation for the mere-exposure effect (Kunst-Wilson & Zajonc, 1980; Zajonc, 1968), the model also explains the fluency–liking link by proposing that fluency is subjectively experienced as an unspecific feeling, which can become a powerful source in the formation of evaluations and preferences (Schwarz & Clore, 1988). However, in their studies, Bornstein and D’Agostino only assumed and did not test that a subjective feeling had been elicited

This article was published Online First October 22, 2012.

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by their perceptual manipulations, as no direct measure for these feelings was taken.

Reber, Wurtz, and Zimmerman (2004) more directly addressed the status and role of subjective feelings of fluency. They showed that objective perceptual fluency manipulations of both contrast and type of font fed into a subjective feeling of fluency as revealed by effects on experienced readability. These findings indicated that the subjective feeling of fluency can be reported following an objective manipulation of fluency. Still, however, it remained unclear whether experienced readability was a reflection of a subjective feeling of fluency. In other words, the hypothesis that a component of feeling of easiness or fluency can be falsely attributed to an object and facilitate its liking, requires directly showing that the ease of processing leads to a feeling of fluency, and that the latter has the potential to enhance object liking.

In our experiments, we directly addressed the crucial mediating feeling of fluency by asking our participants to explicitly judge how easy it was for them to perceive the just presented stimulus. This is similar to the approach of Topolinski and Strack (2009a, 2009b) who measured subjective feelings of fluency and liking after manipulating semantic coherence of word triads in a between-participants design. Interestingly, they found that higher fluency was not necessarily felt by their participants (as revealed by subjective evaluations), but nevertheless led to higher liking. The authors reasoned that differences in conceptual fluency were strong enough to trigger an affective reaction, but might have been too weak to be consciously detected as higher felt fluency. Thus, despite that study, it is still an open question whether subjective feelings of fluency could facilitate liking. Moreover, each participant of Topolinski and Strack's experiments judged each object only once. In this manner, object repetitions were prevented as one source of increased fluency and liking. A drawback of this approach, however, is that object preferences could have reflected between-participants preferences that existed prior to and regardless of the fluency manipulations. To allow a within-participant manipulation of object evaluation by fluency in the present study, we therefore took another approach. Every stimulus was presented twice, and we used priming and stimulus duration as fluency manipulations. This enables us to track the liking and subjective fluency ratings to our fluency manipulations. Using a perceptual fluency manipulation instead of a conceptual manipulation enables the study of relationships between fluency and liking at an early perceptual level.

To study the role of subjective feelings of experienced fluency, we directly asked our participants for their *felt fluency* (FF). Thus, in two experiments, subjective (feeling of) fluency ratings of stimuli were registered as a dependent variable in every trial. As independent variables, we employed two perceptual manipulations of processing fluency (as in Reber et al., 1998). We call these the manipulations of *ease of processing*. In the first experiment, we used subliminal perceptual priming as an objective manipulation of ease of processing. In the second experiment we explored whether manipulation through varying the presentation duration influences the FF and liking rating. Most crucially, we also compared the FF with the objective manipulation of ease of processing as alternative determinants of liking. If the ease of processing is as powerful as feelings of fluency, liking should be facilitated by ease of processing, regardless of the participants' FF. However, if FF

matters, liking should be facilitated even more when the participants felt that perception was easier.

Experiment 1

In the first experiment, we used subliminal perceptual priming to manipulate the ease of processing of line drawings of simple everyday objects. During subliminal priming, one stimulus, the prime, is masked so that it remains below the level of awareness, and it is presented prior to a visible and task-relevant target stimulus (Dehaene et al., 1998; Marcel, 1983). In this situation, a congruent prime that resembles the target in its appearance or meaning facilitates processing of the target (Ansong, Kiefer, Khalid, Grassl, & König, 2010; Kiefer, 2002). This facilitation is evident when compared with a neutral or incongruent prime that is perceptually less similar to the target or its meaning (Greenwald, Draine, & Abrams, 1996; Martens, Ansong, & Kiefer, 2011). Through congruent priming, the processing ease of a target image should be increased and, according to the fluency-liking hypothesis, the target should be liked more (see Reber et al., 1998). By prompting FF as well as liking ratings, the relationship between these two dimensions can be studied. Following the recommendation of Bornstein and D'Agostino (1992, 1994), we used subliminal masked priming to conceal the source of fluency and therefore to avoid that fluency would be discounted.

Method

Participants. Fifty undergraduate psychology students (43 women) from the University of Vienna took part in return for partial course credit. Their ages ranged from 18–31 years ($M = 22.5$, $SD = 3.5$). Participants signed a written consent form and had normal or corrected-to-normal vision.

Stimuli. We selected 150 images (image size: 3.2×2.3 in., or $6.79^\circ \times 4.75^\circ$ of visual angle at a viewing distance of approx. 27.56 in.) from the picture set of Rossion and Pourtois (2004), depicting a variety of everyday objects. Of these images, 100 were selected as target images, and the remaining 50 images were used as incongruent primes. We thereby created the two levels of processing ease: Congruent conditions, with similar prime and target pictures in the same trial, and incongruent conditions, with primes that differed from the subsequent target in the same trial. All images were gray-scale versions. For the line-prime images, we erased all surface texture and shadowing from the original photographic images (see Figure 1 for an example of the images used as prime and target in a trial). We also added 60% Gaussian noise to the original images using Adobe Photoshop CS4. As a consequence, target images were not too easily perceived. Participants had thus no problem understanding their task: to judge how easy they felt it was to perceive the stimuli. Adding noise to the images also fostered perceptual uncertainty, which is favorable for measuring the influence of FF on liking judgments (Schwarz, 2004). To avoid prime visibility, a line mask of 3.2×3.2 in. was used. The mask was created (with Adobe Photoshop CS4) by random lines of the same thickness as in the target images. Masking was tested and ensured during pretesting.

Design and procedure. Each image had to be rated twice, once for FF and once for liking. These measurements were taken independently in two different blocks. Order of blocks (liking first

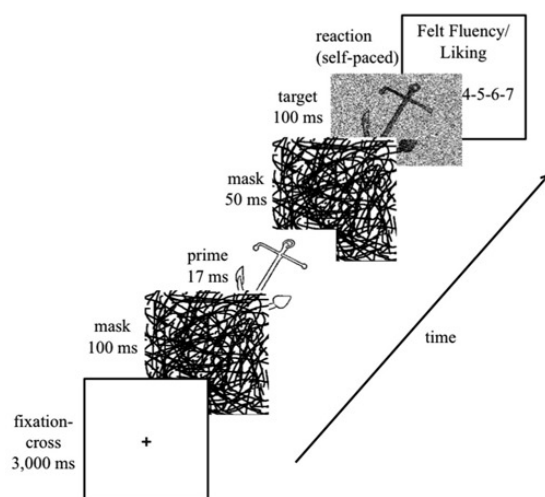


Figure 1. Sequence of a congruent trial (high ease of processing) with respective presentation durations on the left.

vs. fluency first) was counterbalanced across participants. In each block, half of the images were congruently and the other half were incongruently primed. To allow direct comparisons between FF and liking, images that were used as congruent targets in one block were also used as congruent targets in the second block. Also, each image was equally often used in a congruent or incongruent trial. Targets and primes were combined in eight different versions, and each participant was randomly assigned to one of the versions.

To conceal the link between the FF and the liking ratings, participants were told in the instructions that they would take part in two separate experiments: One in which FF would be studied, and another one in which we collected liking ratings for stimulus selection for a later experiment. Each trial started with a fixation cross, presented in the center of the screen for 3 s, and then the mask for 100 ms. Next, the prime was presented for 17 ms (one refresh cycle at 60 Hz), followed again by the mask for 50 ms. Finally, the target was shown for 100 ms, and the participants were subsequently prompted to give their responses (see Figure 1). Depending on block (or task) levels, participants rated either their liking of the stimulus ("How did you like the presented stimulus?") or their FF of perception ("How easy was the perception of the presented stimulus?"). As the images were rather simple, we asked the participants to indicate their FF of each stimulus in comparison with the FF of the other stimuli presented throughout the study. For the trials, the participants were instructed to compare FF with the stimuli from the practice trials, therefore the reference for the subsequent ratings was established during the practice trials. For both ratings, Likert type rating scales from 1 (*not at all*) to 7 (*very much*) were used. Within blocks, the presentation order of the stimuli was random. After completion of all trials, the participants were told about the purpose of the experiment and about the presence of a masked prime. To test the participants' awareness of the primes, in the end participants performed a visibility test: In an additional block, participants were asked to indicate or guess for

each trial whether the prime, seen or not, was congruent or incongruent with the target. All these experimental procedures were run with E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002) and presented on a 19-in. display at a resolution of $1,280 \times 1,024$ pixels and a refresh rate of 60 Hz. After completing all trials, the participants were debriefed and thanked.

Results and Discussion

Visibility test. To test whether the primes were not visible in the first place, we computed d' values for each participant (Macmillan & Creelman, 2005), as d' is a very sensitive index of prime visibility (Reingold & Merkle, 1988). In the present study, d' was calculated as the difference of the z -transformed probability of hits (here, *congruent* judgments in congruent trials) minus the z -transformed probability of false alarms (here, *congruent* judgments in incongruent trials). In the case of the invisibility of the primes, d' equals 0 and can infinitely increase with ever-increasing discrimination performance. The mean d' value significantly deviated from zero, $t(49) = 5.12$, $p < .001$, $M_d' = 0.45$, $SD_{d'} = 0.62$, $d = 0.72$. The mean hit rate was 38% and the mean false alarm rate was 25%. This would indicate that in some cases the primes were visible. By and large, priming effects in "aware" and "unaware" conditions show strong resemblances (see Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003), but a few qualitative differences exist. For example, participants might be more sensitive for the probabilities of congruent versus incongruent trials in aware than unaware priming conditions (Forster, 1998), and, related to this, they might be able to better actively suppress priming after visible incongruent primes than after invisible incongruent primes (Ansoorge, Fuchs, Khalid, & Kunde, 2011; Kunde, 2003; but see Van Gaal, Lamme, & Ridderinkhof, 2010). Furthermore, for the participants, prime visibility might lead to consciously recognizing the priming manipulation as the source of the fluency, and consequently might lead to discounting (Bornstein & D'Agostino, 1992, 1994). Therefore, we computed the 95% confidence interval of d' separately for each participant and excluded all participants ($n = 14$) whose 95% confidence interval did not include zero (Macmillan & Creelman, 2005, p. 325).¹ Consequently, the following analyses are based on participants not aware of the primes ($n = 36$).

Main analysis. To identify rating differences as a function of high and low ease of processing, we performed separate paired t tests for the FF and the liking ratings. The high ease of processing (= congruent) trials ($M = 4.67$, $SD = 0.82$) was perceived as more fluent than the low ease of processing (= incongruent) trials, $M = 4.50$, $SD = 0.81$, $t(35) = 2.18$, $p = .018$ (one-tailed), $d = 0.36$. Furthermore, stimuli in the high ease of processing trials ($M = 4.03$, $SD = 0.56$) tended to be liked more than stimuli in the low ease of processing trials, $M = 3.93$, $SD = 0.45$, $t(35) = 1.66$, $p = .052$ (one-tailed), $d = 0.28$. These results indicated that increasing processing fluency through subliminal perceptual priming influenced both the FF and, to a lesser extent, the liking ratings. Congruently primed stimuli were judged as easier to perceive and were liked slightly more than incongruently primed stimuli.

To analyze the effects of FF on liking (Bornstein & D'Agostino, 1992, 1994), we conducted the following analysis: For each participant, we first split the trials according to whether the subjective

¹ We thank an anonymous reviewer for suggesting this exclusion criterion.

FF rating was below or above this participant's mean FF rating. Next, we computed (a) the mean liking rating and (b) the number of trials contributing to each particular mean liking rating, for (i) low FF trials/low ease of processing, (ii) low FF trials/high ease of processing, (iii) high FF trials/low ease of processing, and (iv) high FF trials/high ease of processing.

Next, to analyze the relative effects and interactions between objective ease of processing and subjective FF, we ran two complementary analyses of variance (ANOVAs), one on mean liking (regardless of the number of trials contributing to each mean), and one on the number of trials (regardless of the mean liking). Table 1 gives an overview of the mean number of trials and the mean liking ratings in each condition separately for high and low FF. Both ANOVAs were run with the independent variables ease of processing (high vs. low) and FF (high FF vs. low FF). The analysis of the mean liking ratings revealed a significant main effect of FF, $F(1, 35) = 166.77, p < .001, \eta_p^2 = .83$, but neither a main effect of ease of processing, $F(1, 35) = 0.11, p = .744, \eta_p^2 = .003$, nor an interaction, $F(1, 35) = 0.02, p = .881, \eta_p^2 = .001$ (see Figure 2). A post hoc paired t test confirmed that liking for high FF trials, $M = 4.48, SD = 0.58$, was higher than for low FF trials, $M = 3.35, SD = 0.42, t(35) = 12.93, p < .001$ (one-tailed), $d = 2.15$ (see Figure 3), which is clear support for the perceptual fluency/attributional model of Bornstein and D'Agostino (1992, 1994). The absence of an interaction effect in the ANOVA shows that FF did not interact with ease of processing, and therefore that FF, rather than ease of processing, is associated with differences in liking (see Figure 2). Accordingly, the differences in effect size also indicate that the influence of FF on liking ($d = 2.15$) was much stronger than the influence of objectively manipulated ease of processing ($d = 0.28$), indicating that FF seems to be the major factor for the liking judgment.

The analysis of the number of trials revealed a main effect of FF, $F(1, 35) = 18.07, p < .001, \eta_p^2 = .34$ and, additionally, an interaction, $F(1, 35) = 5.56, p = .024, \eta_p^2 = .14$. The main effect of FF was a side effect of the counting procedure (see Table 1) and does not necessarily

carry much meaning. Also, the ease of processing could not be computed, as the number of high and low ease-of-processing trials was equal by design. The significant interaction, however, showed that ease of processing did have an effect, at least on feeling of fluency: For low FF judgments, we observed a larger number of low ease-of-processing cases ($M = 23.22, SD = 5.30$) than of high ease-of-processing cases for low FF ($M = 20.86, SD = 4.98, p = .024$), whereas this pattern reversed for high FF judgments, in which there were more high ease-of-processing cases ($M = 29.14, SD = 4.98$) than low ease-of-processing cases ($M = 26.78, SD = 5.30, p = .024$, see Table 1). This interaction shows that ease of processing also had an effect on FF; as expected, proportions of low ease of processing were higher for low FF, and lower for high FF. Nevertheless, these effects were small (23–21, low FF and 27–29, high FF). If the effect were large and FF solely depended on ease of processing, there would have been a much higher difference in the proportion. Furthermore, the analysis also showed that in both ease-of-processing conditions, there were more high than low FF trials.

Correlations. The relation between FF and liking should also be reflected in a significant correlation between the two variables. Thus, we computed the correlation between the FF ratings and the liking ratings for each participant separately. The overall mean correlation was $r(36) = .41, p < .001$. Separating the trials by ease of processing revealed significant correlation coefficients, $r_{\text{high}}(36) = .40, p < .001, r_{\text{low}}(36) = .42, p < .001$, which were similar to each other and also very similar to the overall correlation. These correlations show that the FF is significantly related to the liking rating, a result in line with the assumption that FF is one source for the liking judgments.

Order effects. A repeated-measures ANOVA for FF with block order as a between-participants variable revealed no effect of block order, $F(1, 34) = 0.08, p = .776, \eta_p^2 = .002$, and no interaction between ease of processing and block order, $F(1, 34) = 2.12, p = .15, \eta_p^2 = .06$. For the liking ratings there was also neither a main effect of block order, $F(1, 34) = 0.001, p = .973, \eta_p^2 < .001$, nor a significant interaction between ease of processing and block order, $F(1, 34) =$

Table 1
Mean Number of Trials (N) and Mean Liking Ratings (M -LK) Separately for Low/High Ease of Processing and Low/High Felt Fluency In Both Experiments (for Clarity the Mean Number of Trials Is Rounded)

	Experiment 1			Experiment 2				
	Incon.	Con.	Σ	100	200	300	400	Σ
Low FF								
n	23	21	44	12	10	9	9	40
M -LK	3.35	3.36	3.35	2.95	2.89	3.08	3.13	3.02
High FF								
n	27	29	56	13	15	16	16	60
M -LK	4.47	4.50	4.48	4.36	4.41	4.36	4.45	4.39
Σ								
n	50	50	100	25	25	25	25	100
M -LK	3.91	3.93	3.92	3.66	3.65	3.72	3.79	3.70

Note. FF = felt fluency; Incon. = incongruent; Con. = congruent. The mean FF ratings were floating-point numbers, but all raw-score judgments were integers (from 1 to 7). Therefore, dividing the total number of all trials into those above versus below the mean FF led to a different number of trials above and below the mean. In Experiment 1, compared with the analysis including all participants, an analysis excluding participants with proportions of low FF to high FF trials over 30/70 or 70/30 ($n = 3$) showed a similar effect size ($d = .24$, with a weaker trend of $p = .088$) in differences of liking in relation to ease of processing. All other effects did not change after exclusion of the three participants. In Experiment 2, exclusion of participants over the stated criterion ($n = 24$) led to absence of significance for the main effect of ease of processing and for the interaction between ease of processing and FF in the 2×2 ANOVA, with liking as the dependent variable. As effects of these factors were small in the analysis using all participants, this change in the results may be mainly due to the reduction of sample size.

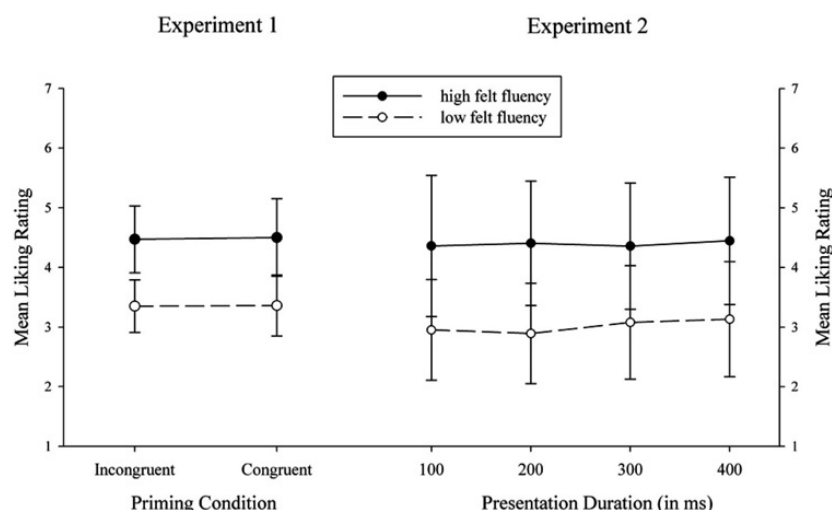


Figure 2. Mean liking ratings for high FF (solid line) and low FF (dashed line) trials in Experiment 1 (left) and Experiment 2 (right). Error bars represent standard deviations.

0.83, $p = .370$, $\eta_p^2 = .02$. Thus, neither the FF nor the liking rating depended on whether the respective judgments were collected first or second.

Experiment 2

In Experiment 1, we found small effects of ease of processing on liking, whereas effects of FF on liking were much stronger. To extend our conclusions from Experiment 1 to supraliminal presentation of stimuli, we conducted a second experiment. In Experiment 2, we tested whether fluency is also experienced as a feeling of ease when the ease-of-processing manipulation concerned an implicit but clearly visible feature of the images.

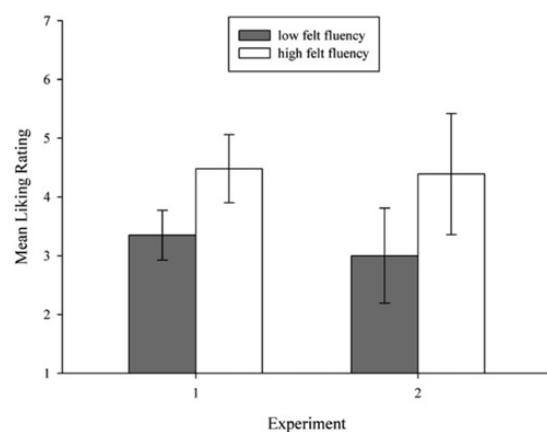


Figure 3. Liking ratings in Experiment 1 (left, $n = 36$) and Experiment 2 (right, $n = 96$) for each ease-of-processing condition and high/low FF. Error bars represent standard deviations.

First, the participants' unawareness of the primes might be a necessary, or at least favorable, precondition for the fluency effect and/or the link between fluency and liking. According to the arguments put forward by Bornstein and D'Agostino (1992, 1994), the fact that the prime remains below the level of awareness is a favorable condition for the misattribution of the ease-of-processing-induced FF to the target stimulus, and hence a liking of this stimulus. On a general level, this assumption is well in line with the known qualitative processing differences between supraliminal and subliminal stimuli. In particular, it has been shown that willing inhibition of priming influences can indeed be stronger with supraliminal than subliminal primes (see Ansorge et al., 2011; Kunde, 2003). For example, Kunde (2003) observed that his participants successfully inhibited the impact of clearly visible primes after an incongruent prime-target sequence. However, the same participants were unable to also ignore subliminal primes if they had just seen an incongruent sequence consisting of a subliminal prime and a supraliminal target. This backs up the reasoning of Bornstein and D'Agostino (1992, 1994). On the other hand, some authors found that manipulations in ease of processing affected fluency even when a supraliminal stimulus feature was used. In their Experiment 3, Reber, Winkielman, and Schwarz (1998) varied the presentation duration of the stimulus, in 100-ms steps, between 100 and 400 ms. As longer presentation durations enabled the perceiver to extract more information from the stimulus image (Mackworth, 1963) and increased ease of processing, accordingly more fluency was experienced by Reber et al.'s (1998) participants. Based on these observations, we wondered whether the link between FF and liking could be confirmed if the ease-of-processing manipulation concerned the supraliminal duration of the primes. If this is the case, we expected that the FF and liking should be higher with longer presentation durations, too.

Method

Participants. Ninety-six undergraduate psychology students (83 women) from the University of Vienna took part for partial course credit. Their age ranged from 18–36 years ($M = 22.1$, $SD = 3.1$). All participants signed a written consent form and had normal or corrected-to-normal vision. None of the participants had taken part in Experiment 1.

Stimuli. The stimuli were the same as the target stimuli in Experiment 1.

Design and procedure. The design was similar to Experiment 1. Each image was rated twice, in one block for FF and in the other for liking. Different from Experiment 1, in which ease of processing was manipulated by congruent versus incongruent subliminal priming, in Experiment 2, ease of processing was manipulated through different presentation durations. The 100 images were divided into four sets of 25 images each. Different presentation durations (100, 200, 300, or 400 ms) were assigned to each of the four sets. The assignment of durations to images was counterbalanced across participants. As in Experiment 1, the order of blocks (liking first vs. fluency first) was balanced across participants. An instruction phase (similar to that in Experiment 1) in the beginning concealed a connection between the liking ratings and the subjective fluency ratings. Each trial started with a fixation cross for 3 s, followed by the target image for 100, 200, 300, or 400 ms. A random noise mask (60% Gaussian noise) followed the target for 500 ms. Then the response was prompted. The FF and liking questions and the rating scales were the same as in Experiment 1. The experimental procedure was controlled by E-Prime 2.0 (Schneider et al., 2002) on a 19-in. display with a refresh rate of 60 Hz at a resolution of $1,280 \times 1,024$ pixels. After completing all the trials, the participants were debriefed and thanked.

Results and Discussion

As in Experiment 1, effects of ease of processing on FF and liking were analyzed separately. A repeated measures ANOVA with *presentation duration* (or ease of processing) as a between-participants factor and FF rating as a dependent variable showed a significant main effect, $F(3, 285) = 31.57$, $p < .001$, $\eta_p^2 = .25$. The means (see Table 2) show a constant increase in the FF rating from 100 to 400 ms. Except for the comparison between the 300 ms and 400 ms condition, all Bonferroni corrected pairwise comparisons were significant (all $ps < .01$). The mean liking ratings show a similar pattern; they also increased constantly from 100 to 400 ms. A repeated measures ANOVA revealed a significant main effect of presentation duration for liking, too, $F(3, 285) = 13.59$, $p < .001$,

$\eta_p^2 = .13$. Bonferroni corrected pairwise comparisons showed a significant difference between the 100-ms condition and both the 300-ms and 400-ms conditions ($ps < .001$, means and standard deviations, see Table 2) and a significant difference between the 200- and the 400-ms condition ($p < .001$). Thus, ease of processing (here, varied across duration) influenced both the FF and the liking ratings in a similar way. Longer presented, objectively easier to process stimuli, were felt to be easier to process and were liked more than shorter presented stimuli. Contrary to the reasoning of Bornstein and D'Agostino (1992, 1994), the supraliminal ease-of-processing manipulation in Experiment 2 apparently did not lead to a correction process and therefore did not discount the effect of ease of processing on liking.

As in Experiment 1, we analyzed ease of processing and FF as within-participant factors with respect to liking in a one-way ANOVA. This analysis revealed a significant effect of FF, $F(1, 94) = 388.06$, $p < .001$, $\eta_p^2 = .81$; a significant main effect of ease of processing, $F(3, 282) = 3.99$, $p = .008$, $\eta_p^2 = .04$; and an interaction between ease of processing (presentation duration) and FF, $F(3, 282) = 2.67$, $p = .05$, $\eta_p^2 = .03$ (see Figure 2). A post hoc paired t test showed that high FF trials ($M = 4.39$, $SD = 1.03$) were liked significantly more than low FF trials, $M = 3.00$, $SD = 0.81$, $t(95) = 20.39$, $p < .001$ (one-tailed), $d = 2.08$ (see Figure 3). For ease of processing, pairwise comparisons only showed a significant difference between the 200-ms condition ($M = 3.65$, $SD = 0.86$) and the 400-ms condition ($M = 3.79$, $SD = 0.94$, $p = .011$). Regarding the interaction, pairwise comparisons revealed that only in one condition, namely, for the low FF stimuli in the 200-ms condition ($M = 2.90$, $SD = 0.84$), liking was lower than in the 400-ms condition ($M = 3.13$, $SD = 0.97$, $p = .003$). No other comparison was significant. As indicated by the differences in the means and the magnitude of the effect sizes, the effect of FF on liking was strong, whereas the main effect of ease of processing and the interaction effect both showed smaller differences in the means and smaller effect sizes (see also Figure 2). We therefore conclude from the ANOVA that there is an impact of both ease of processing and FF on liking, but the impact of FF is relatively stronger than the impact of ease of processing.

As in Experiment 1, we also analyzed the number of cases of high-FF and low-FF trials at all of the four levels of ease of processing (100 ms to 400 ms). The ANOVA revealed a main effect of FF, $F(1, 94) = 80.78$, $p < .001$, $\eta_p^2 = .46$, and an interaction between ease of processing and FF, $F(3, 282) = 25.11$, $p < .001$, $\eta_p^2 = .21$. Also in this analysis, the main effect for ease of processing cannot be computed, as high and low ease-of-processing trials were equally distributed by design. Also, as was the case in Experiment 1, there was a, not particularly meaningful, higher number of high FF trials than low FF trials, which was due to the sorting of raw-score integers, according to a floating point number of mean FF. As in Experiment 1, the interaction effect showed a larger number of low ease-of-processing cases than high ease-of-processing cases for low FF (all pairwise comparisons significant at $p < .002$, except 300 ms vs. 400 ms, $p = 1.00$; means, see Table 1), whereas there were more high ease-of-processing cases than low ease-of-processing cases for high FF (all pairwise comparisons significant at $p < .009$, except 300 ms vs. 400 ms, $p = 1.00$; means, see Table 1). This interaction shows again that ease of processing had an effect on FF. As expected, proportions of low ease of processing were higher for low FF, and

Table 2
Means and Standard Deviations (in Parentheses) Separated by
Presentation Duration in Experiment 2

	Presentation duration			
	100 ms	200 ms	300 ms	400 ms
Felt fluency				
<i>M</i> (<i>SD</i>)	4.97 (0.91)	5.23 (0.89)	5.40 (0.85)	5.44 (0.89)
Liking				
<i>M</i> (<i>SD</i>)	3.71 (0.93)	3.78 (0.90)	3.90 (0.96)	3.98 (0.97)

lower for high FF. Also as in Experiment 1, there were again only small differences between the levels of ease of processing (max. difference 3, low FF and 3, high FF).

Correlations. In Experiment 2 the correlation between the FF rating and the liking rating was $r(96) = .46, p < .001$. Computing the correlation for each presentation duration separately revealed very similar coefficients, $r_{100}(96) = .49, p < .001$; $r_{200}(96) = .49, p < .001$; $r_{300}(96) = .48, p < .001$; $r_{400}(96) = .45, p < .001$. These results again underline the significant relationship between the FF and the liking of a stimulus.

Order effects. A repeated-measures ANOVA for FF, with block order as a between-subjects factor, revealed a main effect of block order, $F(1, 94) = 7.71, p = .007, \eta_p^2 = .08$, but no interaction between block order and ease of processing, $F(3, 282) = 0.57, p = .64, \eta_p^2 = .01$. For liking there was also a significant main effect of block order, $F(1, 94) = 19.26, p < .001, \eta_p^2 = .17$, but again no interaction between block order and ease of processing, $F(3, 282) = 1.02, p = .39, \eta_p^2 = .01$. When fluency was tested first and liking second, ratings for both fluency and liking were higher. This effect might well simply reflect a difference between the participants. However, block order did not produce any interaction with ease of processing.

General Discussion

In this study, we investigated whether the manipulated ease of processing is indeed felt fluent and whether this feeling accounts for the liking of objects. In two experiments, it was shown that the feeling of fluency strongly affected liking and varied with ease of processing.

We directly analyzed the relationship between manipulating ease of processing and subjective feeling of fluency with respect to liking and found that ease of processing influenced the liking ratings to a lesser extent than feelings of fluency. This conclusion is drawn on findings from separate analyses, where effects of FF were much larger than of ease of processing, and from joint analyses. In the latter, no effects of ease of processing were found in Experiment 1, whereas in Experiment 2, effects of ease of processing were significant, but the effect size was small. Nevertheless, additional analyses of the number of cases of low and high FF trials as a function of low and high ease of processing revealed small effects of ease of processing in both experiments. Thus, FF was affected by ease of processing, but liking was mainly determined by FF. Together the results suggest that the feeling of fluency could be a powerful facilitator of attraction in many everyday situations.

A by-product of perceiving a stimulus is a subjective experience (Koriat, 1993). The feeling of fluency of a perceptual process can be seen as an instance of this experience. Our results clearly show that participants reported a subjective difference between the stimuli with respect to the ease of processing, which converged with the objective ease-of-processing manipulation. In our experiments, we directly tested this feeling for each stimulus by asking the participants about the ease of perceiving the stimulus. To our knowledge, this is the first time that this feeling, which is claimed to be the inner representation of the ease of processing (Bornstein & D'Agostino, 1992, 1994; Reber & Schwarz, 2002), has been directly tested for each participant in each trial. Previously used measures, such as effects on experiences of font readability (Reber, Wurtz, et al., 2004) or brightness (Mandler, Nakamura, & Van Zandt, 1987)

were more indirect reflections of the feelings, based on assumed connections between feelings of ease as sources of these judgments. Also, FF and liking ratings in between-participants designs (Reber, Wurtz, et al., 2004; Topolinski & Strack, 2009b) did not allow the clear separation of effects of objective congruency manipulations from preexperimentally existing interindividual differences concerning the FF of perception and the liking of different objects. When exploring the relationship between the feeling elicited by fluency and the liking judgments about the stimuli, we found that measuring both dimensions for each participant ruled out the possibility that preexisting differences between participants account for the ease-of-processing-elicited rating effects. The absence of block order effects in Experiment 1 underlines the feasibility of a within-participant design because this indicates that a one-time stimulus repetition did not negate the influence of more local manipulations of FF or liking, and was, in fact, too weak to be measurable at all.

Different from Topolinski and Strack (2009b), who found no effects of feeling of fluency after conceptual ease-of-processing manipulations, our results do show a substantial effect of FF after perceptual ease-of-processing manipulations. Therefore, manipulating perceptual ease of processing seems to exert a stronger or different effect on the feelings of fluency. The manipulations used here apparently were strong enough. We assume that this can also be a result of the within-participant design, in which there would be less variance to mask the close relationship between the ease-of-processing manipulation and each of the object's evaluations. The new conclusion is that, in every instance in which a stimulus is perceived, there could be a new subjective evaluation that is not simply consistent with a relatively recent—and related—subjective evaluation. Moreover, different contexts (here experimental manipulations) could be powerful sources of independence between repeated evaluations of the same stimulus. Thus, higher fluency through perceptual manipulations does not always enhance liking (see also Unkelbach, 2006). Rather, it is the subjective feeling that determines whether we like something or not. This is akin to many everyday situations, in which one assesses an object very differently in one situation than in another situation. For example, in the summer, one values the removable hard top of a convertible because it will cool down the ride, but in the winter, the same feature can be annoying.

Furthermore, the experiments showed that the feeling could have served as a source for the liking of a stimulus. Thus, the elicited feeling, which was reported by the participants, is one possible source of information relevant to the liking of the stimulus (Clore et al., 2001; Schwarz, 2001; Schwarz & Clore, 1988). Our experiments showed that a higher feeling of fluency led to a higher liking judgment, but not necessarily via the manipulated objective conditions. This suggests that, irrespective of the actual conditions, it was the human feeling or belief about how easy a stimulus was perceived that came along with increased liking. This finding is fully commensurate with the emotion theories, which put an emphasis on the beliefs of humans as one source of the elicitation of emotions. For example, according to the phenomenologist's view on emotions, it is the subjective beliefs about the state of affairs rather than the actual facts that are important for the emotional experience (e.g., Arnold, 1960).

As the liking differences elicited by objective ease-of-processing manipulations such as priming were relatively small,

one might argue that the ease-of-processing manipulation was too weak to show robust effects. However, objective ease of processing did influence the feeling of fluency to a sufficiently reliable extent. Furthermore, there were small but existing effects of ease of processing on liking, which are in accordance with classical research on fluency (Reber et al., 1998). However, the effects of FF on liking were much stronger. This calls for a search for additional factors influencing the relationship between FF and liking, which cannot be explained by the manipulation. From our experiments, we cannot conclude what these additional factors might be. One possibility, however, could be the preexisting differences in liking (or fluency) that we mentioned as a potential threat to the between-participants design. Liked or familiar objects are faster to process than less liked objects, and this preexperimental influence could have shaped our participants' appreciation of at least a few specific stimuli (Schupp, Markus, Weike, & Hamm, 2003; Stolarova, Keil, & Moratti, 2006). For example, the participants could have experienced the presentation of a preexperimentally appreciated stimulus in the incongruent (low ease of processing) and in the congruent (high ease of processing) condition as equally fluent, because the object was appreciated to a maximal extent in the first place and facilitation by appreciation was strong enough to counteract the ease-of-processing manipulation.

Our findings are in accordance with the feeling-as-information account (Schwarz, 2001; Schwarz & Clore, 1983, 1988), which indicates that our feelings are a source for judgment. Based on our experiments, we suggest that the subjective feeling of fluency can be seen as an instance of a feeling, which is then used for a liking judgment. However, we cannot formally rule out the possibility that liking preceded fluency and was subsequently attributed to the stimuli. This, however, does not seem very plausible, because according to this possibility, our objective manipulation of processing fluency, such as our manipulation of stimulus congruence and presentation duration, would have first affected liking, which then would have been felt as fluency. It seems more reasonable to assume that it was the subjective feeling of fluency, which, as the more proximal outcome and more direct measurement, was influenced by objective fluency. Then, the resulting subjective feeling was attributed to liking. Future studies should address this issue, for example, by studying the time course of the interplay between liking and fluency judgments.

Regarding the relationship between our experimental variables, we cannot conclude whether ease of processing influenced FF, which in turn influenced liking, or whether ease of processing and FF both influence liking independently from each other. One possible factor, which could be on the bottom of both the FF judgment and the liking judgment, might be an unspecific activation or arousal. This activation, elicited by the ease-of-processing manipulation, could be felt as the feeling of fluency, which in turn could form the basis for liking ratings. Future experiments measuring this unspecific activation, and furthermore, applying path models, could help test these different courses of processing.

Regarding FF and liking, it is possible that factors besides congruence affected these judgments. For instance, the longer the experiment took, the more stimuli and instances were available for the relative FF judgments. In the current study, these effects of prior experience within the experiment were only tested with respect to block order of judgments, but future studies could include these variables to fully account for FF as well as liking judgments.

Comparing both experiments, the effects were rather similar, which suggests that our effects do not depend on the visibility or conscious experience of the manipulation. This means that FF is used as a source for liking judgments regardless of visibility of the manipulation. For ease of processing, findings of Bornstein and D'Agostino (1992, 1994) suggest that visibility of the manipulation leads to a correction process, in which fluency is discounted as a source of the liking judgment. However, our findings in Experiment 2 suggest that the participants did not correct their liking judgment on the basis of their (assumed) awareness of the objective duration manipulation. There are two possible explanations for this discrepancy. First, some participants might not have perceived the differences in presentation duration and therefore did not discount fluency. Second, for supraliminal variations in presentation duration, fluency is simply not corrected. In a supraliminal priming experiment, participants should consciously experience a repetition of the stimulus (or at least two closely related versions of the stimulus) due to priming. Therefore they may more explicitly recognize the relationship between perceptual priming, that is, the manipulation and fluency, and consequently correct their liking rating (Bornstein & D'Agostino, 1992). In our Experiment 2 however, fluency was manipulated through presentation duration and therefore, though supraliminal, perhaps not explicitly recognized as a fluency manipulation. The reported effects and the absence of any correction in Experiment 2 are in line with the findings of Reber et al. (1998, Experiment 3) and Winkielman and Cacioppo (2001), who also found differences in liking due to manipulations of presentation duration. Consequently, susceptibility of different manipulations of fluency to correction of the liking rating clearly warrants further research.

The fact that the feeling of fluency showed a stronger relationship to liking than the objective ease of processing suggests that the FF, or felt ease, is a more central variable in the fluency-liking link than the objective ease of processing. Furthermore, FF was, at least in our experiments, not influenced by conscious discounting. Analyzing the FF could therefore be a fruitful way of resolving some inconsistencies between experimental results and fluency theories (Reber, Schwarz, et al., 2004). For example, aesthetic preference of complex stimuli, such as artwork, can be explained by the ambiguity elicited by the artwork (Jakesch & Leder, 2009). In the light of the fluency-liking link this may seem counterintuitive at first glance, because ambiguity should be less fluent, and stimuli therefore less liked. In light of our findings, this antagonism may be dissipated by proposing that resolving the cognitive challenge posed by an ambiguous work of art may result in a stronger feeling of fluency, which in turn leads to higher liking, without direct impact of objective ease of processing (less vs. more ambiguity) on the experience of fluency and liking. It will be interesting to test these hypotheses in the future.

Our findings are in line with theories about the feeling of fluency, such as the perceptual fluency/attributional model (Bornstein & D'Agostino, 1992, 1994), which explicitly predicted a connection between felt ease of stimulus perception and liking. In an evaluation phase in which the stimuli were slightly more difficult to perceive, the experience of fluency was attributed to the judgment dimension, which, in our experiments, was the liking. To sum up, our findings suggest that we like what we feel to be fluent rather than what really is fluent.

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Received January 26, 2012

Revision received July 2, 2012

Accepted July 17, 2012 ■

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Summary & Outlook

By manipulating ease-of-processing through subliminal priming (Experiment 1) and presentation duration (Experiment 2), we were able to show that these manipulations were directly accessible to our participants. Manipulating the ease-of-processing consistently led to higher feelings of fluency. Furthermore, we could replicate previous findings showing that higher ease-of-processing leads to higher liking evaluations (e.g., Reber et al., 1998).

By using a less salient (subliminal priming) and more salient (presentation duration) manipulation, we also tested the effects of discounting on the fluency-liking link (Bornstein & D'Agostino, 1992, 1994). Our findings clearly show that the salience of the manipulation—and also the awareness of the participants regarding the manipulation—did not affect the relationship between fluency and liking. In both experiments higher ease-of-processing translated to higher felt fluency and higher liking. Thus, the awareness of the manipulations did not lead participants to discount the feeling of fluency as a source for their evaluations of liking (see also Newell & Shanks, 2007).

To more thoroughly investigate effects of felt fluency on liking, we calculated mean liking ratings for images rated as high or low in felt fluency. Interestingly, we found that participants especially liked those images that felt most fluent. This effect was furthermore independent of the actual manipulation of ease-of-processing. Thus, it seems that individuals prefer what *feels* fluent, rather than what actually is fluent. We further found a strong correlation between felt fluency and liking: the feeling of fluency indeed seems to be strongly related to liking. Thus, our findings corroborate previous theoretical accounts by showing that individuals have a subjective feeling of fluency (Bornstein & D'Agostino, 1994; Reber, Schwarz, et al., 2004). Higher ease-of-processing is reflected in higher feelings of fluency. Those feelings of fluency then translate into higher liking (Schwarz, 2011; Schwarz & Clore, 2007).

By analyzing effects of both the actual ease-of-processing manipulation and the feeling of fluency on liking, we could show that both factors exert their influences on liking evaluations. As the actual manipulation of ease-of-processing strongly influenced the feelings of fluency, one might wonder from where the independent contributions of both factors on liking stem. Following previous findings from Topolinski and Strack (2009c), who found effects of ease-of-processing on liking without effects on felt fluency (note: this was tested between-participants), effects of ease-of-processing might not be fully conscious. Given the pattern of results, higher ease-of-processing could influence liking via conscious and unconscious processes. The conscious part is subjectively felt (the feeling of fluency). The unconscious part is not reflected in a subjective feeling of fluency, but can nonetheless become a source for evaluations. Teasing these two contributions apart is beyond the scope of the present thesis, but could be an avenue for further research.

3) Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation

Introduction

In the previous publication we could show that participants do have a conscious experience of how easy something has been processed (Forster et al., 2013). Furthermore, the felt fluency was more strongly associated with liking than the actual manipulation of ease-of-processing. As the rating of felt fluency was a dependent variable, only correlational relationships with liking were warranted. Thus, in a follow-up paper, published in *Frontiers in Human Neuroscience*, we tried to corroborate and more directly test the previous findings by explicitly manipulating the felt fluency. In addition to the previously used manipulation of ease-of-processing via presentation duration, we manipulated the felt fluency by giving false feedback (Valins, 1966). We made participants believe that we could measure their ease-of-processing via their skin conductance response. Then we presented line-drawings of common objects (Rossion & Pourtois, 2004) and, after each stimulus, gave participants false feedback about their alleged ease-of-processing experience. For this manipulation, participants were told that an increase in skin conductance reflected an increase in ease-of-processing, a decrease in skin conductance reflected a decrease in ease-of-processing. As a control, we gave no feedback in one-third of the trials. After the false feedback, we asked for liking and fluency ratings for each stimulus. As a further source for the felt fluency, we additionally manipulated the actual ease-of-processing by varying the presentation duration of the stimuli (100, 200, 300, or 400ms). As in the previous publication (Forster et al., 2013), higher ease-of-processing was expected to accompany higher liking and higher felt fluency.

As we had two sources of felt fluency, false feedback and presentation duration, we could test how they interact in the formation of a liking evaluation. Either, (a) the clear feedback may be so explicit that it overwrites subtle effects of presentation duration. Thus, we

would only find effects of false feedback. Or, (b), the explicit feedback might lead to discounting of ease-of-processing as a source for evaluations. Previous research has shown that conscious awareness about ease-of-processing might diminish the effects of the manipulation on evaluations (Bornstein & D'Agostino, 1992, 1994; but see Forster et al., 2013; or Newell & Shanks, 2007). The feedback makes individuals aware of the manipulation of the ease-of-processing. This might lead to (b₁) a diminished effect or no effect of false feedback, while leaving the effect of presentation duration intact. Furthermore, through the explicit feedback, the feeling of fluency from varying presentation durations might be discounted as well. Thus, we would find (b₂) no effect at all; neither for feedback nor for presentation duration. Finally (c), both manipulations might exert independent and additive influences on felt fluency and liking.

The mapping between a high skin conductance response and a high felt fluency in our experiment could promote compatibility effects between the feedback curve and the response (Slovic, Griffin, & Tversky, 1990). This means that higher ratings in felt fluency and in liking would be solely due to the fact that the feedback curve increases and not due to the higher felt fluency elicited by the feedback. To rule out this possibility and to further corroborate the findings of Experiment 1, in a second experiment we reversed the mapping between the skin conductance response and the ease-of-processing. Thereby, an increase in skin conductance reflected a decrease in ease-of-processing, while a decrease in skin conductance reflected an increase in ease-of-processing. The control condition without feedback remained the same.

Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation

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OPEN ACCESS

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Received: 04 March 2015

Accepted: 12 June 2015

Published: 26 June 2015

Citation:

Forster M, Fabi W and Leder H (2015)
Do I really feel it? The contributions of
subjective fluency and compatibility in
low-level effects on aesthetic
appreciation.
Front. Hum. Neurosci. 9:373.
doi: 10.3389/fnhum.2015.00373

The causes for the liking of objects are multifaceted. According to the processing fluency account, the ease with which an object is processed leads to a subjective feeling of fluency. This subjective feeling is then interpreted as a positive reaction toward the object resulting higher liking. However, evidence regarding the processes underlying this relation is scarce. To show that the subjective feeling can indeed be responsible for liking, we experimentally manipulated processing ease by providing false physiological feedback (varying skin conductance indicated varying feelings of fluency) and by varying presentation times between 100 and 400 ms while participants viewed line drawings of objects and rated them for liking. A first experiment showed that both false physiological feedback and presentation duration influenced liking. Stimuli primed with a (fake) visualization of a physiological correlate of high ease of processing were liked more than stimuli primed with a low ease of processing. Liking ratings in a no-feedback condition fell between the high and low feedback conditions. To explore possible compatibility effects of coupling visual feedback to the fluency interpretation, in a second experiment we reversed the feedback interpretation—visualization of high skin conductance now indicated low ease of processing. The results show a similar pattern, though the effect was subtler. This indicates that when the coupling of feedback to fluency is less apparent or less compatible, the feeling is less strongly linked to liking. Our results support the claim that variations in the feeling of fluency affect the appreciation of objects in terms of liking. Together, the experiments suggest the contributions of processing ease as well as compatibility to the experience of liking.

Keywords: ease of processing, feeling of fluency, aesthetic appreciation, liking, compatibility

Introduction

Current models of aesthetic appreciation indicate that liking is the result of multiple processing stages operating at higher, but also at lower, cognitive levels (Leder et al., 2004; Jacobsen, 2006; Pelowski and Akiba, 2011). For the effect of low-level properties, such as contrast (Reber et al., 1998) or symmetry (Bertamini et al., 2013; Gartus and Leder, 2013), on liking the theory of processing fluency provides a general explanatory framework (for reviews see Reber et al., 2004a; Alter and Oppenheimer, 2009). The theory states that the ease with which an object (an artwork, a product,

or any other scenery) is processed is accompanied by a subjective feeling of fluency, which serves as a basis for several kinds of judgments and evaluations (Reber et al., 2004b; Forster et al., 2013; Garcia-Marques et al., 2013). This subjective feeling of fluency denotes the experience of variations in the ease of processing. As there are no objective feelings of fluency, the addition of *subjective* strictly speaking is obsolete. It is, however, commonly used to highlight the *experience* of the subject. Therefore, in the following we call this experience the subjective feeling of fluency, or in short, felt fluency.

In a typical experiment on processing fluency, the presentation of images, words, or sentences is manipulated to create conditions of lesser and greater ease of processing. Variations in presentation duration (Forster et al., 2013), contrast (Reber et al., 1998), or clarity (Reber et al., 2004b) are commonly used. Though the processing fluency theory is not limited to a specific level or sensory domain of processing, experiments have mainly tested the impact of the ease of visual processing (i.e., perception) or the ease of memory retrieval (i.e., remembering or recognition). In this article we focus on the ease of visual processing as well.

Participants are able to consciously report variations in felt fluency coming along with variations in processing ease. Furthermore, higher ease of processing, in turn, influences various evaluations, such as liking (Reber et al., 1998; Forster et al., 2013), truth (Dechêne et al., 2010), familiarity (Whittlesea, 1993), or even sensory stimulus properties such as brightness (Mandler et al., 1987) or loudness (Jacoby et al., 1988). Often, the two outcomes of a manipulation of ease of processing, felt fluency and liking, are also positively correlated with each other (see for example Forster et al., 2013). It is, however, still unclear whether we really use the feeling of fluency, i.e., the conscious representation of the ease of processing, for our evaluations. We thus intend to test whether the feeling of fluency indeed influences the liking of a stimulus. In two experiments, we tested whether subjectively felt fluency is indeed a source for our evaluations. Consequently, we contribute to the claim that even such “cold” cognitive processes as perception—or more specifically the dynamics of perception—can influence our aesthetic appreciation of objects (Greifeneder et al., 2011).

According to the theory, the easier something is to process, the more it is liked (Reber et al., 2004a). This is because the feeling of fluency is claimed to be *per se* positive, because it signals a positive state of affairs, error free processing, and absence of threat (Winkielman et al., 2003). This positivity is then attributed to a positive reaction toward the object (Winkielman and Cacioppo, 2001; Topolinski et al., 2009). Others claim that the feeling of fluency is an affectively unspecific activation attributed to a higher evaluation of the object (Bornstein and D’Agostino, 1992, 1994) or that fluency amplifies affective evaluations—positive stimuli are regarded as more positive, negative stimuli as more negative (Albrecht and Carbon, 2014). Conclusive evidence is still lacking. A necessary first step, however, is to understand whether and how the subjective feeling of fluency exerts its influence on people’s evaluations.

Most researchers agree that there is a feeling of fluency, i.e., a subjectively experienced representation of the ease of

processing (Reber et al., 2004b; Regenberget al., 2012; Forster et al., 2013; Jakesch et al., 2013). Though the subjective feeling of fluency is not a necessary precondition for effects of ease of processing on liking—ease of processing not necessarily needs to become conscious (Reber et al., 2002; Topolinski and Strack, 2009)—the feeling of fluency was found to be correlated with liking and usually can become conscious (Reber et al., 2004b; Forster et al., 2013; Jakesch et al., 2013). Although Bornstein and D’Agostino (1992, 1994) argued that conscious reflection on ease of processing leads to a discounting of the ease, and thus eliminates effect on the evaluations, others have failed to show that discounting is an issue (Newell and Shanks, 2007; Forster et al., 2013). Indeed, felt fluency seems to have an even tighter connection to liking than an actual manipulation of ease of processing (Forster et al., 2013). We thus tested whether making participants explicitly believe their feeling of fluency is affected does influence their evaluations of felt fluency and liking.

In two experiments we gave participants false feedback about their ease of processing after viewing a stimulus (Valins, 1966). We told participants that their ease of processing could be objectively measured by recording their skin conductance response (SCR) to the stimuli. In Experiment 1, in each trial our participants received either a fake feedback of high processing ease (increasing SCR curve), a fake feedback of low processing ease (decreasing SCR curve), or, as a control, no feedback.

For the false feedback manipulation to work properly, it was paramount that our participants believed the feedback. Thus, in post-questions we tested whether the participants were naïve to the purpose of the experiment. Prior to data analysis, we excluded all participants who explicitly indicated that they did not believe the instruction or that they explicitly ignored the feedback. The main results are thus only from participants who believed the instruction. For the sake of complete reporting, the analysis including all participants can be found in a Supplementary Material.

A finding that feedback of an increasing SCR leads to an increase in liking, and vice versa, could also be caused by a mere compatibility between the SCR curve and the response (Slovic et al., 1990). To exclude such an explanation, in a second experiment we reversed the meaning of the SCR feedback: a decrease in the SCR curve now indicated a higher ease of processing, which should lead to higher liking, and vice versa. We thus switched the mapping between the SCR feedback and the participants’ response. In both experiments, the crucial comparison is between the high and low feedback conditions. If in both experiments a high feedback compared to a low feedback leads to higher felt fluency and liking ratings then the conscious reflection of the subjective feeling of fluency does influence liking.

As a second source of the subjective feeling of fluency in both experiments we manipulated the actual ease of processing by varying the presentation duration of the images between 100 and 400 ms, a manipulation proven successful in previous studies on fluency (Reber et al., 1998; Winkielman and Cacioppo, 2001; Forster et al., 2013). The longer the stimuli are presented, the more information can be gathered, the easier they are to process (Mackworth, 1963), and the higher the felt fluency. Thus the felt fluency participants could use as a source for their evaluations

consisted of the feeling derived from an actual variation in ease of processing and of the false feedback. An effect of the variations in presentation duration on liking should replicate earlier findings that longer presentation durations and thus higher ease of processing is linked to liking (Reber et al., 1998; Winkielman and Cacioppo, 2001; Forster et al., 2013).

Having two sources of felt fluency—presentation duration and feedback—furthermore allows studying how these two sources interact. If we find an effect of feedback alone, it would mean that a conscious representation of felt fluency overrides the actual presentation duration manipulation of ease of processing and governs the liking evaluation. If both the feedback and the presentation duration have an effect or if they interact—feedback of high ease of processing amplifies the effects of presentation duration on liking and feedback of low ease of processing attenuates the effects of presentation duration—then both sources of felt fluency have their share in the evaluations. If the false feedback leaves liking uninfluenced, then the conscious representation leads to discounting of feelings of fluency as a source for our evaluations (Bornstein and D'Agostino, 1992, 1994).

Experiment 1: Materials and Methods

Participants

In Experiment 1, 58 participants believed the feedback manipulation and were thus eligible for further analysis. The sample consisted of volunteers recruited by the experimenter or undergraduate students from the University of Vienna participating in return for partial course credit. Three participants were removed from the final sample, because they failed to show sufficient visual acuity (tested before the experiment). Thus, the final sample consisted of 55 participants

(46 female, $M_{age} = 23.4$ years, $SD = 4.5$). All participants provided written informed consent prior to their participation. Participants were informed that participation and data collection were fully anonymous and that they could withdraw at any time during the experiment without any further consequences. The experiments were conducted in accordance with the Declaration of Helsinki (revised, 1983) and the guidelines of the Faculty of Psychology, University of Vienna. According to the Austrian Universities Act 2002 (UG2002), which was active at the time the experiments were performed, only medical universities were required to appoint ethics committees for clinical testing, application of medical methods and applied medical research. Therefore, no ethical approval was sought.

Stimuli

For the experimental trials we used a selection of 120 line drawings of common objects (Rossion and Pourtois, 2004). As the original images were very easy to perceive, all images were overlaid with 60% Gaussian noise in Adobe Photoshop. This also improved the plausibility of our manipulation of the ease of processing. For the practice trials, 9 famous images (for example the Coca-Cola logo, the Mona Lisa) and 9 non-famous images were selected as targets. For the fake skin conductance response (SCR) feedback we generated 200 random wave patterns with Matlab 7.14 (code available upon request). The code was designed to generate images closely resembling a physiological response (see Figure 1 or Figure 3). Out of the 200 images we then chose 40 images, which best represented an SCR increase, and 40 images, which best represented an SCR decrease.

Design and Procedure

As a manipulation of the actual ease of processing, we varied the presentation duration of the stimuli among 100, 200, 300,

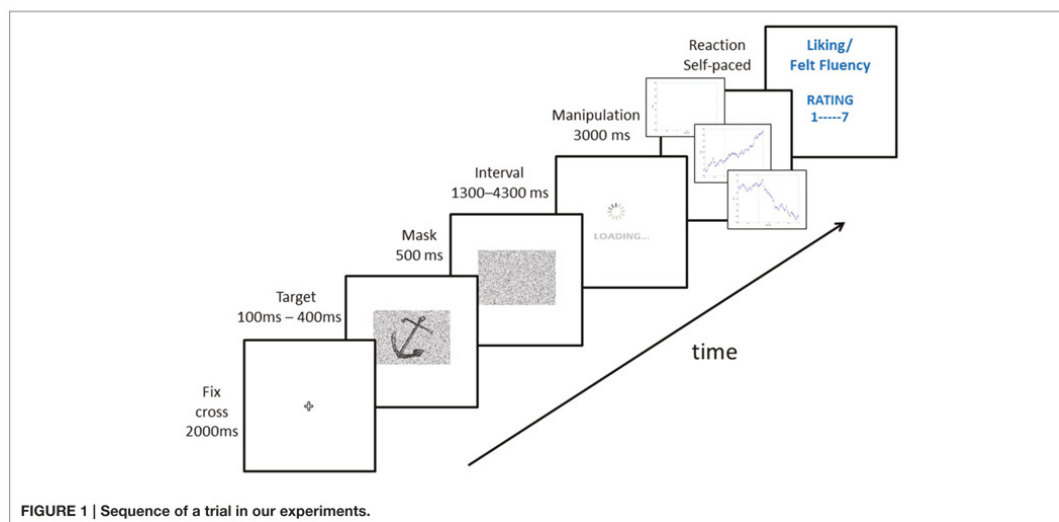


FIGURE 1 | Sequence of a trial in our experiments.

and 400 ms (Forster et al., 2013). For each participant these presentation durations were randomly assigned to the stimuli with the constraint that each of the presentation durations in the end was presented equally often. As a feedback manipulation in each trial after the stimulus presentation, participants received either a feedback of an increasing skin conductance response, representing a high ease of processing feedback, a feedback of a decreasing skin conductance response, representing a low ease of processing feedback, or no feedback. The actual feedback curve image was randomly picked out of the set of possible increasing or decreasing curve images. The type of feedback was randomly assigned to the presentation durations with the constraint of ensuring that for each of the durations each type of feedback was presented equally often. Thus, the factors *presentation duration* and *feedback* were fully crossed.

Upon arrival our participants signed the consent form and performed standardized tests for visual acuity and color vision. Then participants were familiarized with the equipment and the tasks. For our fake physiological measures, we used an 8-channel bioamplifier (Mobi8-BP, TMSI B. V., Enschede, The Netherlands). First, two flat Ag/AgCl-electrodes were placed at the medial phalanges of digits III and IV of the non-dominant hand. As no recording setup was preloaded on the device, no data were recorded. Apart from this fact, everything else was identical to an actual measure of skin conductance. This aimed to increase the credibility of the manipulation.

Prior to the experiment, participants were also familiarized with the plots of the SCR response and participants were led to believe that previous studies have shown that high ease of processing goes along with an increased SCR response. To render the manipulation even more credible 18 practice trials were administered where 6 very famous images (as for example the Mona Lisa) were followed by an increasing SCR feedback and 6 non-famous images were followed by a decreasing SCR feedback. The rest of the images—3 famous and 3 non-famous—were followed by no feedback.

After these familiarization trials, the main experiment begun. In each trial, a fixation cross was first presented for 2000 ms followed by the target for either 100, 200, 300, or 400 ms. Then a mask consisting of random noise was presented for

500 ms to limit visual processing. Then an animated loading screen indicating that the SCR response is being generated was presented for a random time between 1300 and 4300 ms. Both the loading screen and the random time interval were included to make the computation of an actual SCR feedback more plausible. The loading screen was followed by the SCR feedback image presented for 3000 ms. Finally, participants first indicated how much they liked the target (on a 7-point scale ranging from 1 *not at all* to 7 *very much*) and then indicated their felt fluency, i.e., how easy the processing of the stimulus has been (also on a 7-point scale ranging from 1 *not at all* to 7 *very much*, see **Figure 1** for an illustration of a trial sequence). The felt fluency measure also served as a manipulation check for the false feedback.

In total, participants performed 120 trials. In the end the participants were thanked for their participation and thoroughly debriefed about the purpose of the experiment. The whole experiment took around 30 min and was run with e-prime 2.0 (Schneider et al., 2002) on a display with a resolution of 1280 × 1024 pixels at 60 Hz.

Experiment 1: Results and Discussion

To investigate the effects of a false feedback and an actual variation in ease of processing, we performed two separate repeated measures analyses of variance (ANOVAs). First, as a manipulation check, we performed a 4 (presentation duration: 100, 200, 300, or 400 ms) × 3 (feedback: high, low, or absent) ANOVA with ratings of felt fluency as the dependent variable. To investigate whether our manipulations lead to effects in the judged liking of the stimuli the same ANOVA was run with liking as the dependent variable. For the ANOVA we first averaged the ratings of each participant over stimuli separately for the four presentation durations and the three feedback conditions. For the overall means sampled over participants and stimuli see **Table 1**. In all analyses, the level of statistical significance was $p < 0.05$. When the sphericity assumption was not met, the Greenhouse-Geisser correction was applied and the corrected degrees of freedom are reported. For analyses of presentation duration, we performed linear trend analyses, given the hypothesis that ratings of felt fluency and liking should linearly increase with

TABLE 1 | Means and standard deviations (in parentheses) for ratings of felt fluency and liking in both experiments separately for presentation duration and feedback.

Rating		Experiment 1			Experiment 2		
		Low EOP	No FB	High EOP	Low EOP	No FB	High EOP
Felt fluency	100	4.32 (1.07)	4.51 (1.08)	4.80 (0.83)	4.38 (1.06)	4.51 (0.94)	4.69 (1.00)
	200	4.58 (0.93)	4.81 (0.81)	5.07 (0.90)	4.64 (0.94)	4.97 (0.82)	5.12 (0.92)
	300	4.70 (1.02)	4.92 (0.81)	5.15 (0.81)	4.97 (0.87)	5.07 (0.94)	5.27 (0.82)
	400	4.83 (1.10)	5.07 (0.85)	5.24 (0.80)	4.89 (0.98)	5.31 (0.87)	5.38 (0.93)
Liking	100	3.57 (0.94)	3.81 (0.98)	3.84 (0.97)	3.57 (1.04)	3.59 (0.90)	3.68 (0.97)
	200	3.72 (0.98)	3.78 (0.97)	3.86 (0.99)	3.69 (1.03)	3.81 (1.04)	3.73 (0.95)
	300	3.72 (0.87)	3.83 (0.95)	3.96 (1.06)	3.79 (0.96)	3.77 (0.99)	3.85 (1.02)
	400	3.85 (0.94)	4.00 (1.00)	4.01 (1.05)	3.74 (1.02)	3.91 (0.95)	3.93 (0.97)

Low EOP, feedback curve indicating a low ease of processing; No FB, no-feedback curve; High EOP, feedback curve indicating a high ease of processing.

longer presentation durations. For the analysis of the feedback, we compared the mean ratings in the low feedback condition with the mean ratings in the high feedback condition employing *t*-tests.

Felt Fluency

The repeated measures ANOVA with felt fluency as the dependent variable showed significant main effects of both presentation duration, $F_{(2.4, 128.39)} = 19.94, p < 0.001, \eta_p^2 = 0.27$, and feedback, $F_{(1.30, 70.11)} = 15.29, p < 0.001, \eta_p^2 = 0.22$, but no interaction, $F_{(4.70, 253.54)} = 0.17, p = 0.970, \eta_p^2 = 0.003$. Linear trend analysis shows that ratings of felt fluency linearly increased with longer presentation durations, $F_{(1, 54)} = 37.99, p < 0.001, \eta_p^2 = 0.41$ (see Table 1 and Figure 2). For the feedback manipulation, a *t*-test showed that ratings of felt fluency were significantly higher in the high feedback condition ($M = 5.07, SD = 0.72$) than in the low feedback condition ($M = 4.61, SD = 0.90, p < 0.001$). Interestingly, the mean in the no-feedback condition lay between the two feedback conditions ($M = 4.83, SD = 0.75$; no vs. high, $p < 0.001$, no vs. low, $p = 0.006$, see Figure 2). In line with the manipulation intention, with longer presentation durations and with high SCR feedback stimuli were judged as easier to perceive than with shorter presentation durations and with low SCR feedback. The facts that ratings in the no-feedback conditions were numerically between high and low feedback and that high and low feedback significantly differed from each other indicate that we successfully made our participants believe that the feedback reflected their ease of processing.

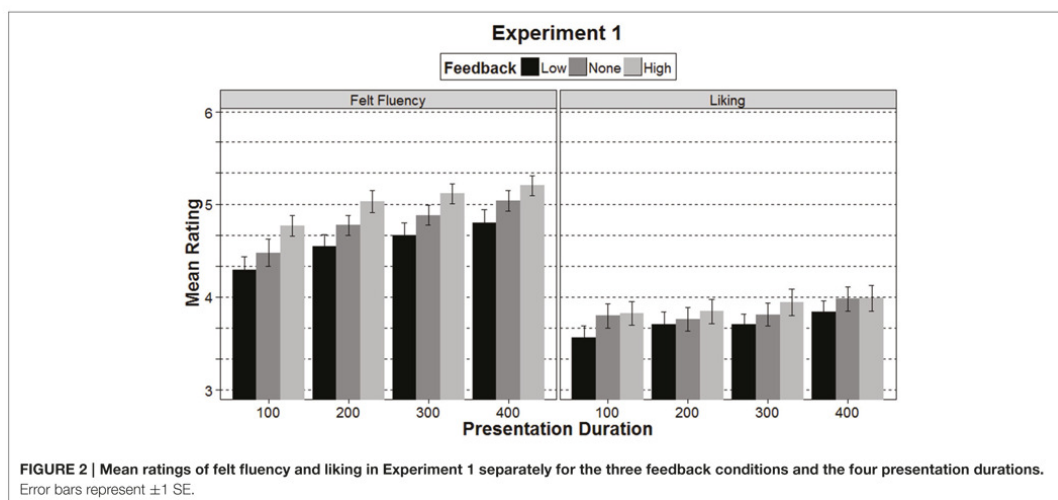
Liking

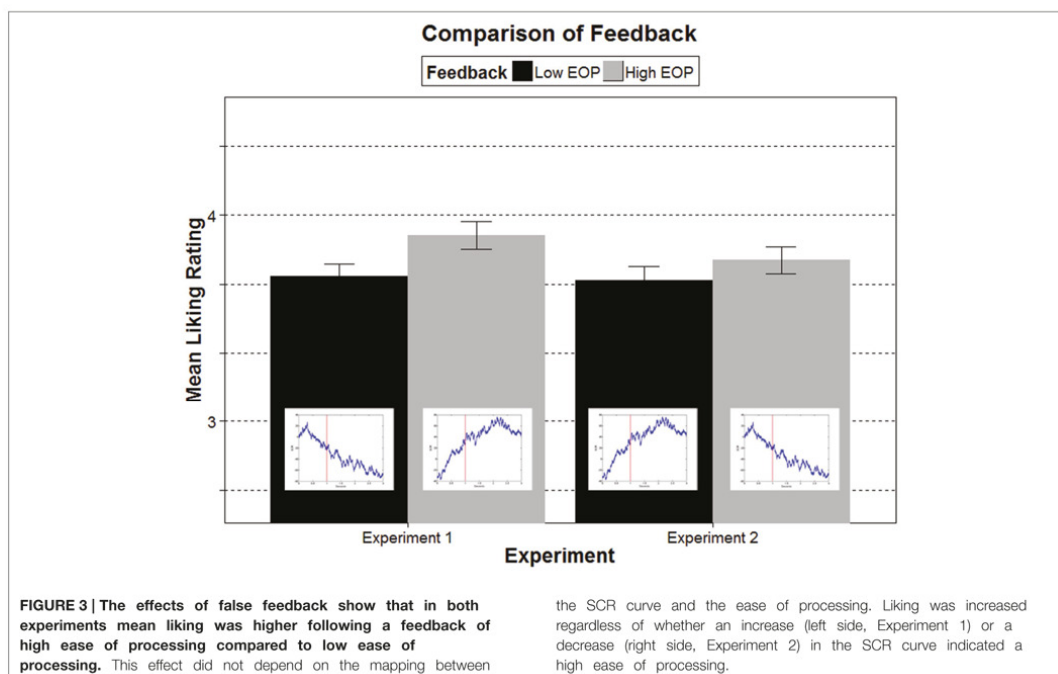
A repeated measures ANOVA testing the influence of presentation duration and feedback on liking ratings showed significant main effects of both presentation duration,

$F_{(3, 162)} = 5.86, p = 0.001, \eta_p^2 = 0.10$, and feedback, $F_{(1.71, 92.11)} = 5.32, p = 0.009, \eta_p^2 = 0.09$, but no interaction, $F_{(6, 324)} = 0.67, p = 0.678, \eta_p^2 = 0.01$. An analysis of linear trends showed that the longer the stimuli were presented the more they were liked, $F_{(1, 54)} = 17.14, p < 0.001, \eta_p^2 = 0.24$ (see Figure 2). For the feedback, a *t*-test showed that stimuli in the high feedback condition ($M = 3.92, SD = 0.96$) were liked more than in the low feedback condition ($M = 3.72, SD = 0.85, p = 0.009$, see left side in Figure 3). Liking ratings in the no-feedback condition were between high and low feedback ($M = 3.86, SD = 0.88$). However, the mean was only significantly different from low feedback ($p = 0.011$), but not from high feedback. These results show that both the actual ease of processing, manipulated through presentation duration, and the false feedback influenced ratings of liking. Both factors exerted their effects on how much the stimuli were liked. Thus, neither did the feedback overshadow the effects of an actual manipulation of ease of processing nor led the conscious reflection through feedback to discounting of felt fluency as a source for liking.

Correlations

To also show that evaluations of felt fluency and liking are strongly related, we performed bivariate correlations. For each participant we first correlated the stimulus ratings of liking and felt fluency both over all conditions and separately for all factor combinations. For further analyses the correlations were Fisher *z*-transformed. The mean correlations presented in the following are the retransformed Pearson correlations. A one sample *t*-test showed a significant positive correlation between felt fluency and liking, $r_{(55)} = 0.42, p < 0.001$. The correlations computed separately for all factor combinations also show significant positive correlation between felt fluency and liking, *rs* between 0.32 and 0.50, *ps* < 0.001. Furthermore,





a 4 (presentation durations of 100, 200, 300, or 400 ms) $\times$ 3 (felt fluency feedback high, low, or absent) repeated measures ANOVA with the Fisher z-transformed correlations as dependent variables yielded no significant effects. This indicates that the correlations are similar in all conditions.

To sum up, Experiment 1 showed that false feedback influenced the liking ratings of our participants. Supporting the theory of processing fluency, participants awarded higher liking ratings to stimuli in trials where a feedback of high ease of processing was provided than to stimuli in trials where a feedback of low ease of processing was given. In trials where no feedback was given, i.e., where participants could only rely on the actual ease of processing, they awarded liking ratings that fell right between the two feedback conditions. These findings suggest that both feedback and the actual ease contribute to a feeling of fluency that is then used as a source for liking.

However, using an increasing skin conductance curve as a feedback of high ease of processing and a decreasing curve as a feedback of low ease of processing we cannot exclude that the effects on felt fluency and liking were due to compatibility between the direction of the curve and the response (Hommel and Lippa, 1995). In the second experiment, we thus instructed a new set of participants that a feedback of an increasing skin conductance response indicated low ease of processing and a feedback of a decreasing skin conductance response indicated high ease of processing. The no-feedback condition was left

unchanged. If the effects were solely due to compatibility then the effects on felt fluency and liking in Experiment 2 should be reversed to Experiment 1.

Experiment 2: Materials and Methods

Participants

In Experiment 2, 56 undergraduate students from the University of Vienna (45 female, $M_{age} = 24.9$ years, $SD = 7.8$), who participated in return for partial course credit, believed the feedback manipulation and were eligible for further analysis. All participants provided written informed consent prior to participation. None of the participants has participated in Experiment 1.

Stimuli

The same stimuli as in Experiment 1 were used.

Design and Procedure

In comparison to Experiment 1, in Experiment 2 the meaning of the feedback was reversed. In Experiment 2, a feedback of an increasing skin conductance response represented a *low* ease of processing feedback and a feedback of a decreasing skin conductance response represented a *high* ease of processing feedback. The no-feedback condition remained unchanged. Accordingly, we adapted the introductory texts and the practice trials to reflect the changes in the meaning of the

skin conductance response. Everything else was identical to Experiment 1.

Experiment 2: Results and Discussion

To analyze the effects of our manipulations on ratings of felt fluency and liking we performed two separate 4 (presentation durations: 100, 200, 300, or 400 ms) $\times$ 3 (felt fluency feedback: high, low, or absent) repeated-measures ANOVAs; once with ratings of felt fluency and once with ratings of liking as the dependent variable. In all analyses, the level of statistical significance was $p < 0.05$. When the sphericity assumption was not met, the degrees of freedom were Greenhouse-Geisser corrected. For presentation duration, linear trend analyses were performed and for feedback, we compared the mean ratings in the low feedback condition with the mean ratings in the high feedback condition employing t -tests.

Felt Fluency

An ANOVA with felt fluency as the dependent variable showed significant main effects of both presentation duration, $F_{(2.14, 117.84)} = 39.52, p < 0.001, \eta_p^2 = 0.42$, and feedback, $F_{(1.78, 97.62)} = 22.21, p < 0.001, \eta_p^2 = 0.29$. The interaction between presentation duration and feedback was not significant, $F_{(6, 330)} = 1.22, p = 0.297, \eta_p^2 = 0.02$. Linear trend analysis shows that ratings of felt fluency linearly increased with longer presentation durations, $F_{(1, 55)} = 57.87, p < 0.001, \eta_p^2 = 0.51$ (see Figure 4). Thus, the longer the stimuli were presented the higher the subjective feeling of fluency. Also in line with our manipulation, a t -test showed that ratings of felt fluency were significantly higher following a high feedback ($M = 5.12, SD = 0.79$) than following a low feedback ($M = 4.72, SD = 0.82, p < 0.001$). The no-feedback condition ($M = 4.97, SD = 0.77$) showed ratings in between the two other conditions (all

$ps < 0.007$). These results indicate that (a) an actual higher ease of processing (through variations in presentation duration) was subjectively felt as more fluent and (b) false feedback had the intended effect on felt fluency ratings. This means that although we reversed the mapping, the participants still understood the feedback as intended.

Liking

Analyzing how the manipulations are reflected in the liking ratings, an ANOVA showed a main effect of presentation duration, $F_{(2.56, 140.70)} = 9.49, p < 0.001, \eta_p^2 = 0.15$. Linear trend analysis showed that liking linearly increased with presentation duration, $F_{(1, 55)} = 18.01, p < 0.001, \eta_p^2 = 0.25$. For feedback, the analysis revealed a trend, $F_{(1.70, 93.41)} = 2.55, p = 0.092, \eta_p^2 = 0.04$. This trend is also reflected in a marginally significant difference in a t -test between the mean liking ratings in the high ($M = 3.80, SD = 0.89$) and low feedback condition ($M = 3.70, SD = 0.92, p = 0.071$, see right side of Figure 3). Though not significantly different, the means in the three different feedback conditions indicate that the liking ratings were highest with high feedback, followed by no feedback, and lowest with low feedback (see Table 1 and Figure 4). There was no interaction between presentation duration and feedback, $F_{(4.89, 268.87)} = 0.91, p = 0.471, \eta_p^2 = 0.02$.

With a reversed feedback mapping results for liking seem less clear as in Experiment 1. The effects, though more subtle, work in the same direction as in Experiment 1. Our results indicate two things: First, the effects in Experiment 1 are not solely due to compatibility. If this would have been the case then effects in Experiment 2 should have been reversed to those in Experiment 1. Second, compatibility between the direction of the curve (increase) and a higher rating is nonetheless favorable for effects of feedback on liking. The effects were more pronounced

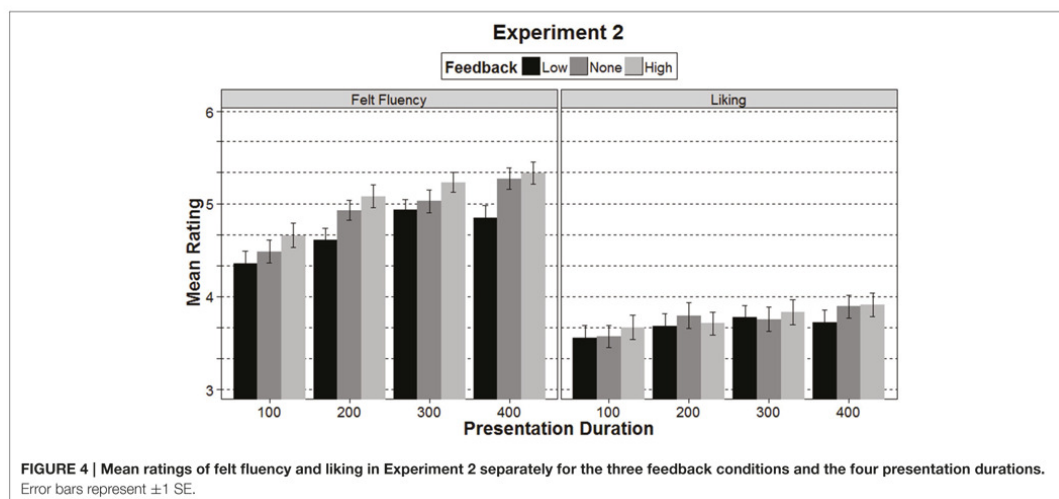


FIGURE 4 | Mean ratings of felt fluency and liking in Experiment 2 separately for the three feedback conditions and the four presentation durations. Error bars represent ± 1 SE.

in Experiment 1, where both false feedback and compatibility work in the same direction.

Correlations

The relationship between felt fluency and liking is also reflected in bivariate correlations between ratings of felt fluency and liking for each participant. Overall, felt fluency and liking are significantly related, $r_{(56)} = 0.46$, $p < 0.001$. The correlations computed separately for all factor combinations also show significant positive correlation between felt fluency and liking, r s between 0.37 and 0.56, all $ps < 0.001$. Furthermore, a 4 (presentation durations of 100, 200, 300, or 400 ms) $\times$ 3 (felt fluency feedback high, low, or absent) repeated-measures ANOVA with the Fisher z -transformed correlations as dependent variables yielded a main effect of presentation duration, $F_{(3, 153)} = 3.52$, $p = 0.017$, $\eta_p^2 = 0.07$. *Post-hoc* pairwise comparisons indicate that the correlations at 100 ms ($r = 0.54$) are significantly higher than at 400 ms ($r = 0.43$, $p = 0.022$). Furthermore, there was a significant main effect of feedback, $F_{(2, 102)} = 3.48$, $p = 0.035$, $\eta_p^2 = 0.07$. Though the means show that without feedback the correlations tended to be higher ($r = 0.53$) than with high ($r = 0.46$) or low ($r = 0.46$) feedback, in *post-hoc* comparisons none of the differences reached significance ($ps > 0.081$). The interaction between presentation duration and feedback was not significant, $F_{(6, 306)} = 1.30$, $p = 0.256$, $\eta_p^2 = 0.03$. Though the findings indicate stronger relations at shorter presentation durations and without feedback, the correlations are all significantly different from 0 and in the range of previous findings (Forster et al., 2013).

General Discussion

In two experiments we tested whether differences in subjective feelings of fluency, manipulated through false feedback when viewing stimuli, influence liking of those stimuli. Such a relationship has generally been claimed in the theory of processing fluency (Reber et al., 2004b; Regenberg et al., 2012; Forster et al., 2013), but up to now remained largely untested. Findings in Experiment 1 clearly indicate that the false feedback, in addition to an actual manipulation of ease of processing, contributes to liking evaluations. Our second experiment highlights the boundaries and requirements for the effect. Under incongruent mapping between feedback curve and response direction—when an increase in skin conductance indicated lower ease of processing and thus should lead to lower liking—the effects of the false feedback were weaker, albeit still in the same direction. Thus, the subjective feeling of fluency is used as a source for liking evaluations given the interpretation of the subjective feeling is straightforward for the perceiver. Effects of presentation duration, an actual variation in ease of processing, were consistent across both experiments: the higher the actual ease of processing, the higher the liking.

In Experiment 1 feedback of a high ease of processing increased felt fluency. Thus, participants correctly understood the feedback trials. Furthermore, for ratings of felt fluency a conscious and clear feedback of how easy something was processed did not lead to discounting of this feeling (see also Newell and Shanks, 2007). Our manipulation of ease of

processing through variations in presentation duration also produced differences in rating of felt fluency, replicating previous findings (Reber et al., 2004b; Regenberg et al., 2012; Forster et al., 2013). Thus, both manipulations contributed to the effect. Though the higher ease of processing not necessarily needs to be consciously represented (Reber et al., 2002; Topolinski and Strack, 2009), we can nonetheless conclude that both our manipulations were successful—and effective—in eliciting a subjective feeling of fluency.

Regarding our main hypothesis, in both experiments feedback of a high ease of processing increased liking; in the no-feedback condition liking ratings fell in between high and low feedback. This indicates that without feedback participants were affected only by the actual ease of processing based on presentation duration. In the high and low feedback conditions the presentation duration manipulation exerted additive and independent effects, as indicated by the significant main effects of both false feedback and presentation duration, and by the absence of any interactions between the factors. Moreover, false feedback did not override effects of ease of processing through presentation duration. Possibly, the manipulations even activated two different processes: one accessible to conscious reflection (false feedback), another inaccessible to conscious reflection (ease of processing). The results of the felt fluency ratings however cast some doubt on this possibility. If our presentation duration manipulation had been impervious to conscious reflection than those variations should not have been reflected in felt fluency ratings.

In Experiment 2 we tested the preconditions and the stability of the effect by reversing the mapping between the skin conductance response and feedback. An increase in skin conductance now indicated a lower ease of processing. In comparison with Experiment 1, we thus excluded that the effects were due to compatibility between an (increasing) feedback curve and (increasing) liking ratings. For ratings of felt fluency we found nearly identical results showing that the manipulation was successful. Despite the reversal of the feedback curve participants reported higher felt fluency after a feedback of high ease of processing compared to a feedback of low ease of processing. Again the no-feedback condition showed ratings in between the two other feedback conditions.

In Experiment 2, the direction of the effects for liking was according to our hypothesis and in the same direction as in Experiment 1. However, we found slightly weaker effects of high vs. low feedback. This is also indicated by only a marginally significant main effect of false feedback. Similar to Experiment 1, the manipulation of ease of processing through presentation duration showed a main effect. This hints that both factors contribute to liking. We can conclude from Experiment 2 that the compatibility between the direction of the feedback curve and the direction of the rating is a favorable precondition for the effect, but not the sole responsible factor. Thus, compatibility seems to ease the attribution of fluency as the source. From the rating of felt fluency we can conclude that the feedback was correctly interpreted. But the participants did not rely on it as strongly as in Experiment 1 (see also Unkelbach and Greifeneder, 2013). The difference in the number of participants who did not believe

the instruction between Experiment 1 ($n = 8$) and Experiment 2 ($n = 40$) also supports the notion that compatibility renders the influence of felt fluency on liking more plausible.

Our correlational analyses in both experiments corroborate the findings just presented. Ratings of felt fluency and liking in both experiments throughout all conditions are significantly related. These results are well in line with previous studies showing that ratings of felt fluency and liking are significantly related (Forster et al., 2013).

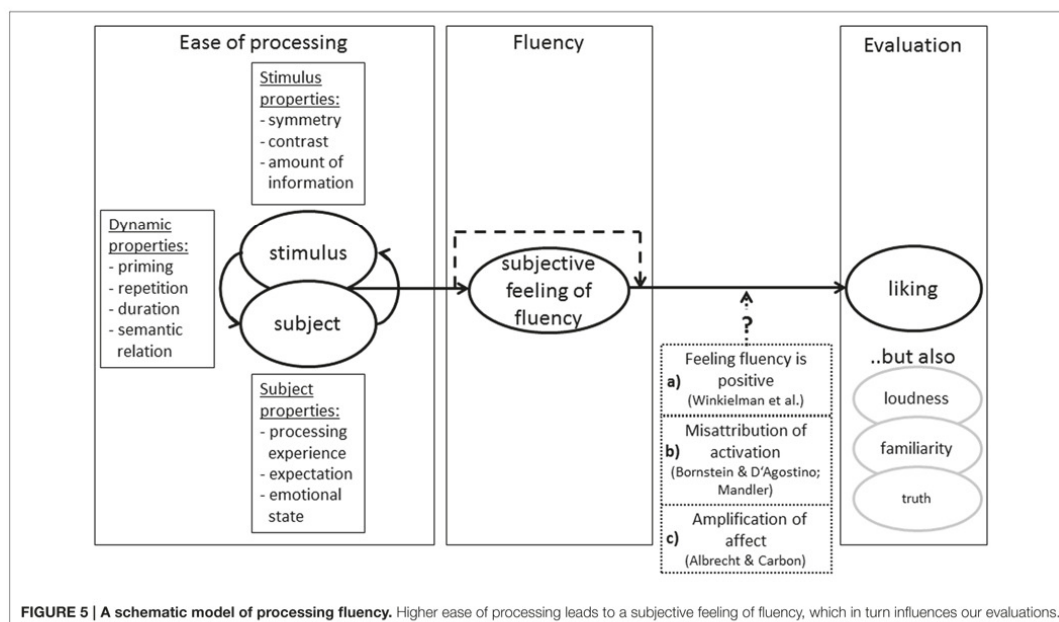
As the results of felt fluency and liking in both experiments are in the same direction and as both ratings are provided in each trial, it is hard to clearly disentangle effects of our manipulations on felt fluency from effects on liking. However, in our instructions at the beginning of the experiments we were careful to only stress the relation between feedback of skin conductance and ease-of-processing. Relationships with liking were never mentioned. Furthermore, using the same measures of subjectively felt fluency and liking, Jakesch et al. (2013) could show that subjective fluency and liking dissociate. As both ratings were provided in each trial, it would also be possible that liking influenced the subjective fluency. There are however no theoretical reasons for why evaluations of liking should influence the feeling of fluency. Also Constable et al. (2013) could show that liking evaluations did not influence response fluency. We, thus assume that in accordance with the processing fluency accounts higher ease-of-processing led to higher liking and not vice versa.

Previous studies testing the effects of a subjective feeling of fluency either ensured in pre-studies that the subjective feeling of fluency is sensitive to changes in ease of processing or used ratings of felt fluency as dependent variables (Reber et al., 2004b;

Regenberg et al., 2012; Forster et al., 2013; Jakesch et al., 2013). Due to the experimental manipulation with a false feedback eliciting a subjective feeling of fluency we can now more safely conclude that this feeling is used as a possible source for our evaluations.

Of course the ease of processing is but one factor influencing our appreciation of objects (Leder et al., 2004; Bulot and Reber, 2012; Leder and Nadal, 2014). Though not yet empirically shown, other factors such as color (Palmer and Schloss, 2010) or personal taste (Vessel and Rubin, 2010) might well interact with the ease of processing in establishing appreciation. At longer exposure and deeper processing, ambiguous objects that pose challenges in perceiving and understanding are appreciated more than easily perceived and understood counterparts (Jakesch et al., 2013). Nonetheless, first impressions and heuristics—especially, when we have no clear preference or other cues are missing—play a role in our everyday evaluations of the environment (see for example in faces, Bar et al., 2006, or brands, Lee and Labroo, 2004). Employing established procedures of previous research we presented rather simple line drawings. With more elaborate material higher-order cognitive processes such as memory integration, personal taste, or expertise might even override the low-level effects (Leder et al., 2004). How the effects in interact with other factors remains to be shown and is a challenge for further research on the formation of aesthetic appreciation.

Our findings, together with previous research on processing fluency (Reber et al., 1998, 2004a; Winkielman et al., 2003), suggest the following preliminary model of processing fluency (see Figure 5): Interactions between a stimulus and a person



looking at a stimulus vary in ease of processing. A number of factors, such as symmetry, priming, or expectations (see Figure 5), contribute to the ease of processing; in our studies variations in presentation duration and false feedback (see also Table 1 in Alter and Oppenheimer, 2009, for a comprehensive overview). Ease of processing leads to a subjective feeling of fluency (Reber et al., 2004b; Regenberget al., 2012; Forster et al., 2013), which can be consciously reported.

The subjective feeling of fluency is then used as a source of information (see Schwarz, 2011, or Schwarz and Clore, 2007, for an overview). Such a feeling of fluency affects liking, but also other evaluations such as judgments of truth (Reber and Schwarz, 1999) or familiarity (Whittlesea, 1993). In Figure 5 a dashed line from ease of processing to liking indicates that ease of processing can influence judgments also without being consciously perceived (Reber et al., 2002; Topolinski and Strack, 2009).

How the feeling influences our evaluations is not yet fully understood. One approach (Box a in the model) suggests that the feeling is *per se* positive, because it signals a positive state of affairs (e.g., Winkielman et al., 2003). Thus, this feeling leads to more positive ratings. Alternatively, the feeling of fluency is an unspecific activation (Mandler et al., 1987; Jacoby et al., 1988) leading to generally higher evaluations irrespective of the valence of the rating dimension (Box b in the model, Bornstein and D'Agostino, 1992, 1994). Another possibility is that the feeling of fluency amplifies the affective evaluation of the stimuli, but leaves affectively neutral stimuli uninfluenced (Box c in the model, Albrecht and Carbon, 2014). Though most evidence is in

favor of the hedonic marking of felt fluency (Fang et al., 2007; Topolinski et al., 2009), conclusive evidence is still lacking (see also Unkelbach and Greifeneder, 2013).

On a theoretical level, the processing fluency account also has its share in the longstanding dissociation between cognition and emotion. In the light of our results, it seems futile to separate such intricately interwoven processes when even such a strictly cognitive process—the perception—has affective components and can influence how much we appreciate our environment (see for example Schwarz and Clore, 2007; Storbeck and Clore, 2007). This tight connection between seeing and feeling is most probably due to a—phylogenetically or ontogenetically—useful preference for the known (Zajonc, 2001; Unkelbach, 2006; Schwarz, 2011). Thus, for aesthetic appreciation we would advise: whenever looking at an artwork, just enjoy the pleasure of the mere perception and indulge in your feeling of fluency.

Acknowledgments

We thank Laura Siegel and Lisa Kröll for assisting in data collection and Andreas Gartus for providing the code for the fake SCR response feedback. This article was supported by the Open Access Publishing Fund of the University of Vienna.

Supplementary Material

The Supplementary Material for this article can be found online at: <http://journal.frontiersin.org/article/10.3389/fnhum.2015.00373>

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Summary & Outlook

In this contribution we tested, in two experiments, whether manipulations in the subjective feeling of fluency indeed influence liking evaluations. In Experiment 1 we showed that false feedback and manipulations of presentation duration exert additive and independent effects on liking. The effect of presentation duration is in line with previous research showing similar effects of higher ease-of-processing on higher liking (Forster et al., 2013; Reber et al., 1998; Winkielman & Cacioppo, 2001). The effects of false feedback have, however, not yet been shown. Here, we found that an explicit feedback about the alleged ease-of-processing influenced liking, independently of how easy the stimulus actually was to process. Feedback of a high ease-of-processing led to higher liking than feedback of a low ease-of-processing.

Experiment 2 showed that the above effect is fostered by a clear relationship between the (increasing) feedback curve and the (increasing) rating. In Experiment 2 the effects were similar to Experiment 1, albeit weaker. However, we can rule out that the effects in Experiment 1 were purely driven by compatibility between the feedback curve and the ratings. If this were the case, then in Experiment 2 the effects would have been opposite to Experiment 1, which was not the case.

In both experiments we found effects of presentation duration and false feedback on liking and felt fluency. False feedback neither overwrote effects of presentation duration nor did it lead to discounting effects. The findings from the previous and the present contribution led to the formation of a preliminary model of processing fluency, which is thoroughly described in the publication and will be presented in the General Discussion in more detail (see Fig 2, p. 215).

Taken together, these experiments on the subjective feeling of fluency demonstrate that participants are sensitive to manipulations in ease-of-processing, as reflected by higher

felt fluency (Forster et al., 2013; see also Jakesch et al., 2013; Reber, Wurtz, et al., 2004; Regenberg et al., 2012). The experimental manipulation through false feedback eliciting a subjective feeling of fluency also gives strong evidence that this feeling is used as a source for evaluations.

4) Exploring the subjective feeling of fluency

Introduction

Our previous studies show that participants have an insight into their feeling of fluency and can report this. In the following contribution (revised version submitted to *Experimental Psychology*), we tested the affective nature of these feelings. As the term *feeling* already suggests, the experience of fluency seems to have an affective component. Furthermore, two main accounts of processing fluency differ in how they conceive the quality of these feelings. The perceptual fluency/attributional account (Bornstein & D'Agostino, 1992, 1994) conceives fluency as a *neutral* and *affectively unspecific* activation that is attributed to evaluations. The account of the hedonic marking of fluency (Reber, Schwarz, et al., 2004; Winkielman et al., 2003), on the other hand, conceives fluency as being *positive* per se. They argue that higher fluency signals error-free processing and absence of threat, thus experiencing fluency is positive (see also above for a thorough discussion of this issue, pp. 18-21).

To pit these two alternative accounts against each other we conducted two experiments. In the first experiment we tested whether variations in ease-of-processing (presentation duration 100, 200, 300, or 400 ms) are attributed to the two core dimension of affect, valence and arousal (Russell, 1980, 2003). We furthermore tried to disentangle effects of higher ease-of-processing on the evaluation of the stimulus and on the evaluation of the participants' feelings. We thus had four different experimental conditions: Rating of (1) stimulus valence, (2) stimulus arousal, (3) the participants' own valence, (4) the participants' own arousal. Thus, in (1) participants rated how positive or negative the stimulus was, in (2) how arousing the stimulus was, in (3) how positive or negative they currently felt, and in (4) how aroused they currently felt. To assure that our manipulation was successful in each

condition we also measured the feelings of fluency in a separate block (as in the previous contributions above).

The rationale behind this experiment was the following: If the feeling of fluency is an unspecific activation then there should be no specific difference between the conditions. As previous research has shown, higher ease-of-processing can be attributed to such divergent dimensions as brightness, darkness, loudness, or truth (Alter & Oppenheimer, 2009b). Due to the unspecific nature, arousal ratings of both the stimulus and the participant should be especially affected. However, if fluency is positive per se, then especially valence ratings should be influenced. Arousal, on the other hand, which is orthogonal to valence (Russell, 1980, 2003) and by definition not clearly positive, should not be influenced by higher ease-of-processing.

Testing affective components on a purely behavioral level bears the danger that subtle affective reactions might not be reflected in the ratings. Previous research has shown that higher ease-of-processing elicits subtle positive affective reactions in facial muscles leading to higher liking (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001). Nonetheless, these reactions may be too elusive to be consciously perceived by participants. Thus, the reactions might not be reported as higher valence. To overcome this limitation we measured the physiological affective responses of valence and arousal while participants rated their feelings of fluency in a second experiment. The manipulation of ease-of-processing was the same as in Experiment 1.

Affective reactions of valence were measured by applying facial EMG (fEMG). Measuring the activation of two facial muscle regions, the M. corrugator supercilii (frowning muscle) and the M. zygomaticus major (smiling muscle), allows insights into automatic positive or negative affective reactions (Tassinary & Cacioppo, 2000). Positive affect is

indicated by an activation of the *M. zygomaticus major* and an inhibition of the *M. corrugator supercilii*. Negative affect is mainly indicated by an activation of the *M. corrugator supercilii*.

Previous research has mainly focused on the measurement of valence (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001). However, to also capture the effect on arousal (the unspecific activation) we additionally applied measures of skin conductance (SC). Measuring the conductivity of the skin tissue, with two electrodes attached to the fingers, offers a physiological measure of arousal (Boucsein, 2012; Dawson, Schell, & Filion, 2000). Higher arousal increases sweat production and thus the conductivity of the skin tissue increases. To our knowledge arousal has not yet been measured in research on processing fluency. Only in the realms of familiarity have measures of arousal been taken. Here the results were, however, mixed. While most studies indicate that novelty, and thus lower fluency, leads to higher SC responses (see Dawson et al., 2000, for an overview), few studies have shown that familiarity leads to higher SC responses (Tranel, Fowles, & Damasio, 1985, but see Ellis, Quayle, & Young, 1999) or higher SC amplitudes (Morris et al., 2008).

Regarding the two divergent accounts we have the following predictions: If fluency is positive then higher ease-of-processing should be reflected in positive activation patterns of the facial muscles. However, if fluency is an unspecific activation then higher ease-of-processing should be reflected in higher skin conductance.

Original Manuscript

RUNNING HEAD: FLUENCY AND AFFECTIVE PROCESSING

Exploring the subjective feeling of fluency

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Abstract

According to the processing fluency theory, higher ease of processing a stimulus leads to higher feelings of fluency and more positive evaluations. However, it is unclear whether feelings of fluency are positive or an unspecific activation and whether feelings of fluency are directly attributed to the stimulus even without much positive feelings. In two experiments, we tested how variations in the ease of processing influenced feelings of fluency and affect, in terms of evaluations (Exp. 1) and physiological responses (Exp.2). Higher feelings of fluency were associated with more positive stimulus ratings and did not affect stimulus arousal ratings, but perceivers' feelings showed higher felt arousal ratings and left felt valence ratings unaffected. Physiological indices only showed small effects of a subtle positive reaction. These findings show that feelings of fluency can be sources of positive object evaluations, but do not affect not of one's own positive feelings.

Keywords: feeling of fluency, ease of processing, arousal, valence, evaluation;

Exploring the subjective feeling of fluency

According to the feelings-as-information theory, feelings can impact our everyday judgments (Schwarz, 2011). One source for these feelings is processing fluency, which is the ease of processing a stimulus¹. Previous research showed that individuals can consciously report feelings of fluency coming along with a higher ease of processing (Forster, Leder, & Ansorge, 2013; Reber, Wurtz, & Zimmermann, 2004; Regenberg, Häfner, & Semin, 2012; but see Topolinski & Strack, 2009). However, it is yet unclear how these feelings of fluency impact affective evaluations. Therefore, in two experiments we tested how variations in the ease of processing influenced feelings of fluency and affect, in terms of evaluations (Experiment 1) and physiological responses (Experiment 2).

In a first behavioural experiment we tried to identify whether the feeling of fluency is associated with the affective evaluation of the perceived object and/or the perceivers' evaluations of their own feelings. This influence was tested on the two core dimensions of affective processing, valence and arousal (Russell, 2003). In a second experiment we applied a combined measure of facial electromyography (fEMG) and skin conductance (SC) to test whether feelings of fluency are hedonically marked (as indicated by fEMG activation) and/or reflect (valence-independent) arousal (as indicated by skin conductance variation).

The theoretical rationale of our study was the following: The theory of processing fluency states that higher ease of processing leads to a higher subjective feeling of fluency within the perceivers, which, in turn, can influence their evaluations of, for example, liking, familiarity or truth (for an overview see Reber, Schwarz, & Winkielman, 2004). This connection between fluency and evaluations can be explained as follows: Ease of processing signals a positive state of affairs, error-free processing, and absence of threat (Winkielman, Schwarz, Fazendeiro, & Reber, 2003). Thus, ease of processing signals safety and therefore is said to be positively valenced (see also Zajonc, 2001). Previous research has shown that the

ease of processing can be subjectively felt and reported (Forster et al., 2013; Reber, Wurtz, et al., 2004). When evaluating how much an object is liked, ratings for easier to process stimuli are enhanced because the positive feeling elicited by the ease is falsely interpreted as a positive reaction towards the stimulus. Empirical tests of the intrinsic positivity of ease of processing are, however, sparse (see Gerger, Leder, Tinio, & Schacht, 2011; Topolinski, Likowski, Weyers, & Strack, 2009; or Winkielman & Cacioppo, 2001, for notable exceptions).

Yet, some findings in processing fluency remain difficult to explain by an intrinsic positivity of the feeling of fluency. Higher ease of processing increases evaluations also on dimensions without a clear valence, such as stimulus brightness or darkness (Mandler, Nakamura, & Van Zandt, 1987), or loudness (Jacoby, Allan, Collins, & Larwill, 1988). These findings were accommodated with a perceptual fluency/attributional account (Bornstein & D'Agostino, 1994). This account states that higher ease of processing is subjectively felt as valence -independent unspecific activation, which is then attributed to the stimulus. Recent evidence furthermore suggests that fluency experiences do not unanimously lead to more positive evaluations. Manipulating the ease of processing of negative, neutral and positive IAPS pictures, Albrecht and Carbon (2014) could show that higher processing ease amplified the affective evaluation; with higher processing ease, positive IAPS pictures were rated more positively and negative IAPS pictures more negatively. Neutral IAPS pictures were not affected by the manipulations.

To sum up, previous research on processing fluency suggested that the feeling of fluency, elicited by a higher ease of processing, is either of positive valence or an unspecific activation. In both cases this feeling should be attributed to the stimulus as its origin so that an evaluation of the stimulus should reflect the influences of ease of processing. To shed light on this explanation, in a first experiment we measured the effect of a fluency manipulation on

evaluations of stimuli on the two core dimensions of affective processing: In one group valence was evaluated—representing a positive or negative reaction—and in a second group arousal was evaluated—representing the valence-independent unspecific activation.

Depending on the theory, there are different predictions for these two dimensions: First, if ease of processing is positive, stimuli should be evaluated more positively with higher ease of processing. Stimulus arousal ratings, on the other hand, might or might not increase with higher ease of processing, as high arousal is not necessarily of positive valence. According to the circumplex model of emotions, a high arousal can be characteristic of positive affect, such as when feeling excited, but it can also be characteristic of negative affect, such as when feeling alarmed (Russell, 1980, 2003). Second, if ease of processing elicits a valence-independent unspecific activation, stimulus arousal ratings should increase with higher ease of processing. Following the notion of Bornstein and D’Agostino (1994), who claimed that stimulus ratings on all dimensions are influenced by higher ease, also stimulus positivity ratings should increase with higher ease of processing.

Moreover, the first experiment addresses a second important question regarding the feeling of fluency. According to the theory of processing fluency, the ease of processing a stimulus leads to a feeling of fluency, which then affects the evaluation of the stimulus. In previous studies, mainly this evaluation of the stimulus was measured. It is thus unclear whether and how the feelings of the perceivers themselves are affected. Since long it is clear that attributions of emotions can occur quickly (Arnold, 1960). Therefore, the second aim of the study was to identify whether the feeling of fluency, elicited by the stimulus, is only reflected in the evaluation of the stimulus or whether evaluations of the participants’ own feelings are affected as well. On the one hand, it is possible that interpreting their feeling of fluency the perceivers feel aroused or positive themselves. On the other hand, if felt fluency is directly attributed to the stimulus which elicited the feeling of fluency, a higher feeling of

fluency might not be felt as generally positive or arousing, but might only be found in the evaluations of the stimulus.

We tested these possibilities by including two additional conditions, in which two separate groups of participants in each trial were asked to rate their feeling of valence or arousal. If the feeling of fluency directly affects the evaluation of the stimulus, the perceiver might not feel aroused or more positive. On the other hand, if the feeling of fluency changes the feelings of the perceivers, which persist even if they are attributed to the stimulus as their origin, the evaluations of the perceivers about their own feelings might be affected, too.

Capturing the affective nature of the feelings of fluency with self-reports offers insight into the consciously accessible and reportable experiences participants have after a manipulation of processing ease. However, those parts of the fluency experience that influence our evaluations without being consciously accessible or which are only experienced at the “fringes of consciousness” (Reber, Fazendeiro, & Winkielman, 2002; Topolinski & Strack, 2009) can hardly be captured by self-reports. Thus, in a second experiment we measured physiological indices of valence (fEMG) and arousal (SC) while a new set of participants performed a similar experimental task as in Experiment 1.

The method of facial electromyography (facialEMG) allows unobtrusively measuring even subtle changes of affective processing (see for example Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008; Larsen, Norris, & Cacioppo, 2003). Affectively positive responses are indicated by activations in the M. zygomaticus major region, a muscle region involved in smiling, and by relaxations in the M. corrugator supercilii region, a muscle region involved in frowning. Affectively negative responses are indicated by activation in the M. corrugator supercilii region. Previous research has already successfully demonstrated that manipulations of ease of processing influence fEMG activation (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001). Thus, if fluency is hedonically marked (Winkielman et al.,

2003), high ease of processing should lead to activation in the *M. zygomaticus major* region and relaxation in the *M. corrugator supercilii* region.

Measuring the skin conductance (SC) allows capturing the autonomic arousal (Boucsein, 2012). The skin conductance response (SCR) to a stimulus occurs around 1 – 3 s after stimulus onset (Morris, Cleary, & Still, 2008). The effect of ease of processing on indices of autonomic arousal has, to our knowledge, not yet been studied. According to the perceptual fluency/attributional account (Bornstein & D'Agostino, 1994), suggesting that higher ease of processing results in a valence-independent unspecific activation, we should find higher SCRs with higher ease of processing. Research on feelings of familiarity, an adjacent concept to feelings of fluency (Whittlesea & Williams, 2000, 2001a, 2001b), showed mixed findings on the association between skin conductance and familiarity. Typically, higher SCRs are associated with stimulus novelty (see Dawson, Schell, & Filion, 2000, for an overview). However, for example in faces, higher SCRs were also associated with higher familiarity (Tranel, Fowles, & Damasio, 1985, but see Ellis, Quayle, & Young, 1999). According to Morris et al. (2008), different task demands might be responsible for these inconsistent findings. They argue that when the task demands attention to novelty, novel items are more salient and show higher SCRs. However, when the task demands attention to familiarity, familiar items are more salient and show higher SCRs (see also Öhman, 1979). Studying the feelings of familiarity Morris et al. (2008) could furthermore show that familiar (and thus easier to process) stimuli compared to unfamiliar stimuli were associated with longer SCR latencies. This indicates that reactions to familiar items are slower. Taken together, previous research allows no clear predictions regarding the effect of ease of processing on the SCR. Nonetheless, following the notion that feelings of fluency could be a valence-independent unspecific activation and the fact that higher ease of processing makes a stimulus more salient, we expected higher SCRs at higher ease of processing.

To sum up, addressing the questions of the affective responses to manipulations of ease of processing helps clarifying the nature and effect of feelings of fluency. Moreover, we gain insights into how incidental feelings influence our everyday judgments.

Experiment 1

Method

We studied the effects of an ease of processing manipulation on ratings of valence and arousal of both the stimulus and the perceiver. We manipulated the ease of processing by varying the presentation duration of the images between 100 and 400 ms. In previous research, manipulations of image duration led to reliable effects on a (usually not measured and only assumed) subjective experience of ease of processing—that is the feeling of fluency (Forster et al., 2013)—and on (usually measured) liking evaluations (Forster et al., 2013; Reber, Winkielman, & Schwarz, 1998; Winkielman & Cacioppo, 2001). Previous research suggests that awareness of the manipulation is detrimental for effects of fluency on liking (so-called discounting, see Bornstein & D'Agostino, 1994; but see Newell & Shanks, 2007). Although a manipulation of feelings by stimulus duration may be apparent for the participants in hindsight, it seems that the participants do not always recognize the duration manipulation as a source of the ease of processing and therefore the effects of the manipulation seem to be resistant against discounting (see for example Forster et al., 2013; or Reber et al., 1998).

Participants. A total of 192 German-speaking volunteers (130 female, $M_{age} = 23.17$ years, $SD_{age} = 5.25$) participated. The sample consisted of students recruited over the departments' participant system and of volunteers recruited by the experimenters around the University premises. In post-questionnaires we ensured that all participants were naïve regarding the purpose of the experiment. Prior to the experiment, all participants signed a consent form informing the participants that they could withdraw at any time during the

experiment without any further consequences. Furthermore, we ensured that participants had sufficient visual acuity (close reading test by Nieden, Oculus[®], Wetzlar, Germany) and color vision (plates 1, 11 and 13 of Ishihara, 1917).

Stimuli. As stimuli, we selected 100 black-and-white images (size: 3.2×2.3 inch, or $6.79^\circ \times 4.75^\circ$ of visual angle at a viewing distance of 27.56 inches) from the picture set of Rossion and Pourtois (2004). This set comprises 260 simple line drawings of objects (e.g., a tree, an anchor, a dog, etc.). As too high/low valences might override the effect of ease of processing, prior to the experiment, all stimuli were pre-rated on valence ($N = 7$ participants). Nine stimuli with very high and six stimuli with very low valence were excluded from the initial set. For the remaining stimuli the mean was between 3.5 to 5.8 on a 7-point scale ranging from 1 to 7. From the remaining stimuli we selected two sets of 50 images each. In these sets complexity, familiarity (both ratings provided by Rossion & Pourtois, 2004), and valence were roughly equal. Because all drawings were initially easy to perceive, difficulty was increased by adding 60% Gaussian noise to the images using Adobe Photoshop CS4. This manipulation avoids floor effects in felt fluency ratings. Furthermore, noise increases perceptual uncertainty, a favourable precondition for measuring felt fluency (see also Forster et al., 2013).

Design and procedure. The feeling dimensions (valence, arousal) and the rating dimensions (stimulus evaluations, participants' feeling) were crossed, resulting in four different conditions that varied between participants ($n = 48$ per condition). Thus the four conditions differed from each other in the evaluations participants made—that is, evaluations about how arousing (Condition 1) or positive (Condition 2) the stimulus was, or how aroused (Condition 3) or positive (Condition 4) the participant felt. Upon arrival, each participant was pseudo-randomly assigned to one condition. In each condition, we also tested whether the ease of processing manipulation affected felt fluency (Forster et al., 2013). For this purpose,

in a separate block we asked our participants to evaluate their felt fluency. The longer the stimulus has been presented, the higher the feeling of fluency should be.

Thus, the participants rated each image twice; in one block on the feeling dimension—valence or arousal—and in the other block on felt fluency. Block order was balanced across participants. Ease of processing was manipulated through different presentation durations. For that purpose, we divided the pool of stimuli into four sets of 25 images each. Next, we assigned one of four presentation durations (100, 200, 300 or 400 ms) to each of the four sets. Across participants, we varied the assignment of stimulus sets to presentation durations according to a Latin square design. Thus, for each condition there were eight versions: 4 (set $\times$ presentation duration) $\times$ 2 block orders. This assured that across all participants each stimulus was presented at all four different presentation durations and that effects of block order were testable.

The experiment started with an instruction in which participants were told that they should rate line drawings in two separate experiments. This instruction was intended to conceal the link between felt fluency evaluations and affective evaluations. After the general instruction, four practice trials were administered to familiarize the participants with task and stimuli. Each experimental trial started with a fixation cross for 2 s, followed by the target image for 100, 200, 300, or 400 ms. Next, to limit visual recognition, a random noise mask (60% Gaussian noise) was presented for 500 ms. Finally, the response was prompted (see Figure 1). Depending on the condition, in one block participants rated either stimulus valence or arousal, or felt valence or arousal² on a 9-point self-assessment manikin (SAM) scale (Bradley & Lang, 1994; modified by Irtel, 2007). Following Forster et al. (2013), participants rated their felt fluency of perception (“Wie leicht ist es Ihnen gefallen das Bild wahrzunehmen?” [“How easy was the perception of the image?”]) on a Likert-type scale from 1 (*very hard*) to 7 (*very easy*) in a separate block. Because the stimuli in all trials were only

mildly emotionally toned—being simple schematic line drawings of objects—we asked the participants to evaluate felt fluency and valence/arousal in comparison with the felt fluency and the valence/arousal elicited in other trials. For the first trials, we instructed participants to compare felt fluency and valence/arousal to the practice trials. In other words, the reference for the subsequent ratings was established during the practice trials. Within the blocks, presentation order of the stimuli and different durations were randomized. After completing the experiment, the participants were debriefed and thanked. The experiment was run using E-Prime[®] 2.0 (Schneider, Eschman, & Zuccolotto, 2002) and was presented on a 19” display at a resolution of 1,280 × 1,024 pixels and a refresh rate of 60 Hz.

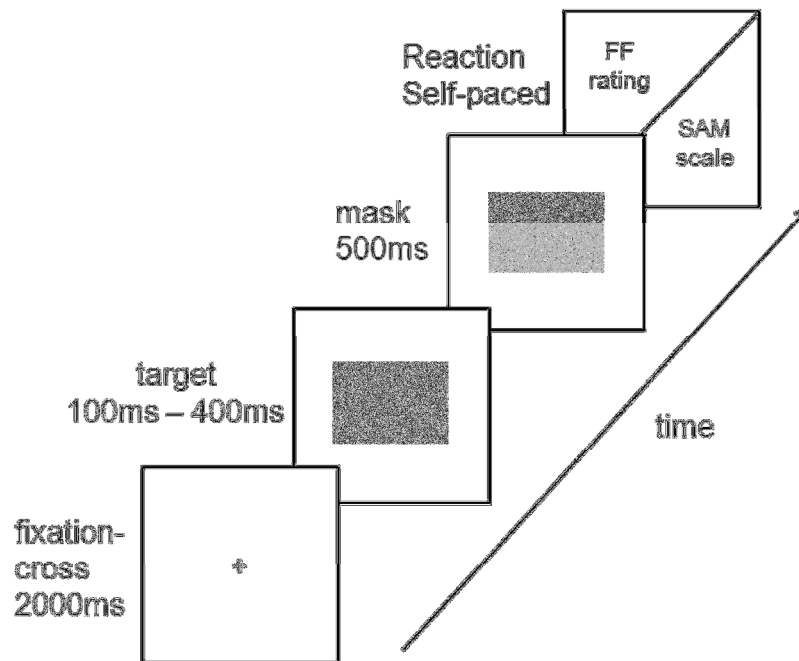


Figure 1. Sequence of a trial in Experiment 1. FF: felt fluency.

To help distinguishing the participants’ valence/arousal evaluations of the stimulus from the participants’ valence/arousal evaluations of their feelings, throughout the Results section we used the terms *stimulus valence/arousal* and *felt valence/arousal*, respectively.

Results and Discussion

To investigate whether ease of processing influenced the feeling dimensions and felt fluency, we performed two separate $4 \times 2 \times 2$ mixed-design analyses of variance (ANOVAs): one for the feeling dimensions valence and arousal, and one for felt fluency. Ease of processing (presentation duration: 100, 200, 300, or 400 ms) was a within-participants variable. The feeling dimension (valence, arousal) and the rating target (stimulus, participants' feeling) were between-participants variables. The respective ratings of valence, arousal, and felt fluency served as dependent variables. In all analyses, the level of statistical significance was $p < .05$. When the sphericity assumption was violated, a Greenhouse-Geisser correction was applied and the corrected degrees of freedom are reported. For multiple pairwise comparisons, the level of alpha was Bonferroni-corrected.

For the feeling dimensions (valence and arousal), the ANOVA showed a significant main effect of ease of processing, $F(2.5, 464.36) = 8.74, p < .001, \eta_p^2 = .04$, and of feeling dimension, $F(1, 188) = 103.68, p < .001, \eta_p^2 = .36$. As indicated by the means (see Table 1), ratings of both valence and arousal in the 100 ms condition were significantly lower than in the 200, 300, and 400 ms conditions, respectively ($ps < .016$), and valence ratings were higher than arousal ratings. The main effect of rating target was not significant, $F(1, 188) = 0.04, p = .949, \eta_p^2 < .001$. The significant main effects, however, were qualified by a significant three-way interaction between ease of processing, feeling dimension, and rating target, $F(2.47, 464.36) = 5.07, p = .002, \eta_p^2 = .03$. Thus, we analysed the pattern of the mean differences with pairwise comparisons (Bonferroni-corrected). For stimuli, the valence ratings (100 ms vs. 200, 300, and 400 ms, respectively, $ps < .027$), but not the arousal ratings ($ps > .849$), significantly increased with increasing presentation duration. For ratings of the perceivers' feeling, the arousal ratings (400 ms vs. 100 and 200 ms, respectively, $ps < .052$), but not the valence ratings ($ps > .557$), significantly increased with increasing presentation

duration (see Figure 2). This dissociation indicates that when rating a stimulus, a higher feeling of fluency is attributed to a higher valence, as predicted by the theory of processing fluency. However, when rating the personal feeling, a higher feeling of fluency is instead attributed to a higher arousal. This latter finding indicates that positive stimulus evaluations are not due to a general positive feeling on the side of the perceiver which is then attributed to the stimulus, but rather that higher ease of processing directly influences the liking of the object.

Table 1

Means and Standard Deviations (In Parentheses) Separated by Presentation Duration in all Four Conditions

			Presentation duration			
Feeling dimension	Rating		100 ms	200 ms	300 ms	400 ms
	target					
Valence	Stimulus	<i>M (SD)</i>	5.16 (0.79)	5.39 (0.80)	5.49 (0.77)	5.57 (0.89)
	Felt	<i>M (SD)</i>	5.09 (0.63)	5.20 (0.58)	5.20 (0.53)	5.27 (0.48)
Arousal	Stimulus	<i>M (SD)</i>	3.71 (1.35)	3.75 (1.23)	3.71 (1.19)	3.63 (1.11)
	Felt	<i>M (SD)</i>	3.74 (1.39)	3.85 (1.44)	3.90 (1.56)	4.06 (1.56)

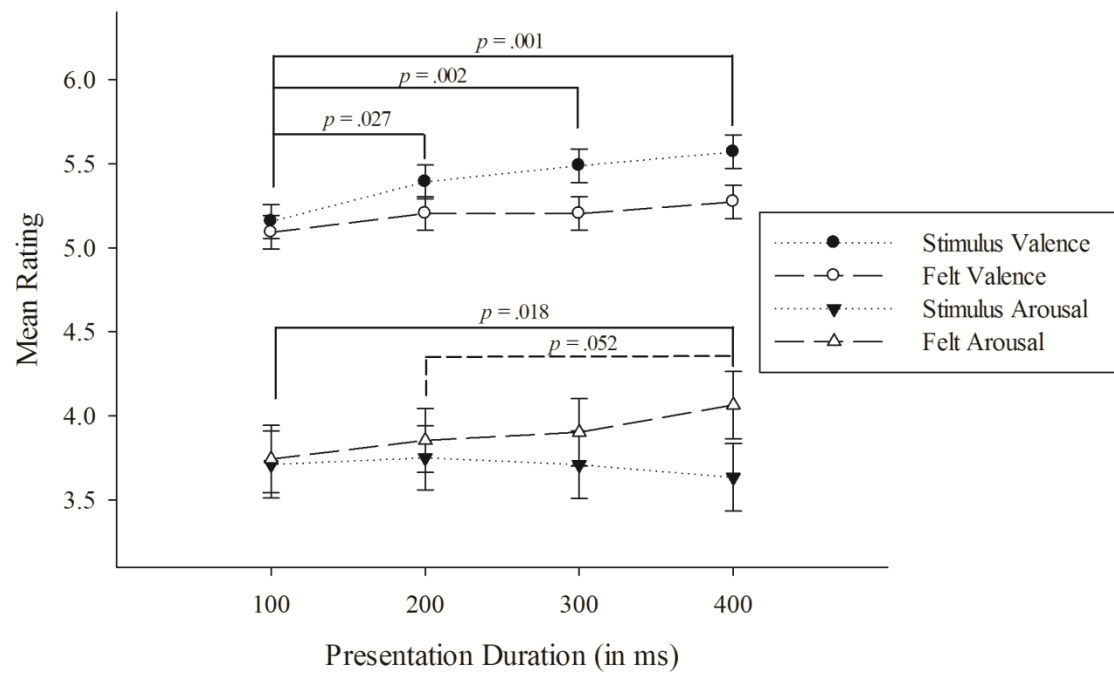


Figure 2. Mean scores for ratings of stimulus (dotted line) and felt (dashed line) valence (circles) and arousal (triangles). Significant effects are indicated by p values (from Bonferroni-corrected pairwise comparisons). Error bars represent standard errors of the mean.

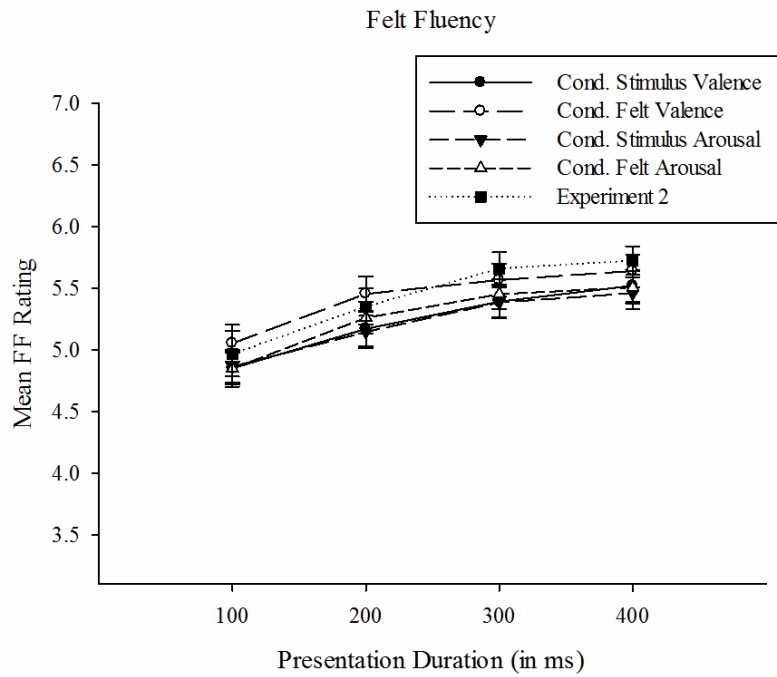


Figure 3. Mean ratings for felt fluency in all four conditions of Experiment 1 and in Experiment 2 (all pairwise comparisons, $p < .007$, except 300 ms vs. 400 ms. Error bars represent standard errors of the mean. Cond.: condition; FF: felt fluency).

For felt fluency, the mixed-design ANOVA only showed a main effect of ease of processing, $F(2.6, 482.44) = 116.80$, $p < .001$, $\eta_p^2 = .38$ (see Figure 3). None of the other effects approached significance ($ps > .321$). Pairwise comparisons showed that the longer the stimuli were presented, the higher the felt fluency (all pairwise comparisons, $p < .001$, except 300 vs. 400 ms, $p = .055$). This finding is in line with previous findings showing that differences in ease of processing can be explicitly reported (Forster et al., 2013; Reber, Wurtz, et al., 2004). Crucially, it also shows that differences in felt fluency were present in all the conditions and that the four conditions did not differ in the ratings of felt fluency. Thus, the above stated differences in the influence of ease of processing on the feeling dimensions are unlikely to be caused by differences in the feeling of fluency. It is rather likely that for stimulus valence and felt arousal fluency is more used as a source and for stimulus arousal and felt valence it is less so.

Ratings of felt fluency and ratings of arousal and valence are based on the same stimuli. Showing the same images in the felt fluency block and the feeling dimension block

allows stronger conclusions regarding the relationship of felt fluency and evaluated feeling dimensions. This procedure, however, might lead to confounding effects of block order and especially of additional fluency due to stimulus repetition. Therefore, in an additional analysis we tested for possible effects of block order. For the sake of parsimony only significant effects including block order will be reported.

For the feeling dimensions, a $4 \times 2 \times 2 \times 2$ mixed-design ANOVA (all factors from above plus block order) yielded a significant interaction between rating target and block order, $F(1, 184) = 6.32, p = .013, \eta_p^2 = .03$. For stimuli, but not for feelings, ratings were higher in the second than in the first block ($p = .019$). This indicates a mere exposure effect (Zajonc, 2001) of repeated presentation on stimulus ratings. As the effect is the same for arousal and valence—indicated by the absence of any interactions between block order and the feeling dimensions—this effect does not challenge our conclusions. All other effects including block order were not significant ($ps > .078$).

For felt fluency, a $4 \times 2 \times 2 \times 2$ mixed-design ANOVA (all factors from above plus block order) yielded a significant main effect of block order, $F(1, 184) = 10.47, p = .001, \eta_p^2 = .05$. Felt fluency ratings were significantly higher when tested first. This finding is not compatible with a mere exposure explanation, which would predict higher felt fluency ratings when stimuli are repeated. Maybe participants recognized the repetition and, as a consequence, fluency effects were discounted (Bornstein & D'Agostino, 1994). Be that as it may, fluency effects as a consequence of the duration manipulation remained intact. This was indicated by the absence of an interaction between duration effects and block order. In summary, block order does not challenge the conclusions from our main analyses.

Though the behavioural results indicate that participants consciously experienced fluency, in Experiment 2 we assessed the affective components of fluency experiences by physiological measures. By measuring fEMG and skin conductance responses we might

capture some affective effects of ease of processing manipulations that are not consciously accessible or reportable.

Experiment 2

Method

Participants. A total of 26 university students (18 female, $M_{age} = 22.6$ years, $SD_{age} = 5.7$) were recruited via the departments' participant system and participated in return for partial course credit. As in Experiment 1, all participants had sufficient visual acuity, color vision and were naïve to the purpose of the experiment. Prior to the experiment, all participants signed a consent form, informing the participants that they could withdraw at any time during the experiment without any further consequences.

Stimuli. The same stimuli as in Experiment 1 were used.

Design and procedure. Due to the nature of the physiological measurement our experimental design had to be slightly adapted. Testing all four conditions, both feeling dimensions and both rating targets, in a physiological setting was not feasible due to the intricacies of the physiological recording and due to availability of only few participants. We thus resorted to testing felt fluency, the block that was common to all conditions. Thus, we measured fEMG and skin conductance responses while participants rated the felt fluency of the processing of the stimuli. Both the manipulation of ease of processing through presentation duration (100, 200, 300, 400 ms) and the stimuli were the same as in Experiment 1.

Upon arrival participants filled out the consent form and were informed about the procedure. Then physiological measures were prepared. For measuring fEMG, two Ag/AgCl electrodes each (4 mm diameter, 7 mm housing) were placed over the left M. corrugator supercilii and left M. zygomaticus major region resulting in a bipolar measurement (following

the guidelines by Fridlund & Cacioppo, 1986). As ground, a single Ag/AgCl electrode was placed on the right mastoid (behind the ear). To reduce electrode impedance prior to electrode placement the skin was cleaned with alcohol (70 % Isopropyl alcohol) and abrasive gel was applied (Nu Prep, Weaver, USA). For measuring skin conductance, Velcro[®] strip electrodes were attached to the palmar middle phalanges of the index and middle finger of the non-dominant hand (see Boucsein, 2012). To assure optimal measuring conditions participants were told to wash their hands in tepid water prior to electrode attachment. For better conductivity EC 33 conductive gel (Grass Technologies, West Warwick, RI, USA) was applied between the skin and the electrodes. Then all electrodes were connected to the amplifier (TMS International Refa8, 32 channel amplifier, TMSi, Twente, The Netherlands) and impedance was checked (to be below 10 k Ω).

As physiological measures afford both a certain period in which the signal can be acquired and an inter-trial interval during which the activation can return to a baseline level, the trial structure had to be adapted as well. Furthermore, a reviewer suggested that presenting the fixation cross for 2 seconds in Experiment 1 might have been too long³. This might have resulted in participants exactly not looking at the middle of the screen and thus in detrimental effects on the perception of the target image. We thus changed the duration of the fixation cross to 200 ms. Similar to Experiment 1, the fixation cross was followed by the target stimulus for either 100, 200, 300, or 400 ms. The target was followed by the same random noise mask as in Experiment 1. The mask was, however, presented for 5 s. Although activation of both fEMG and SC were measured continuously, the activation following the target (i.e., during the presentation of the mask) was of main interest (see below for further details). After the mask, participants rated their felt fluency (“Wie leicht ist es Ihnen gefallen das Bild wahrzunehmen?” [“How easy was the perception of the stimulus?”]) on a Likert-type scale from 1 (*very easy*) to 7 (*very hard*)⁴. To allow the activation to return to baseline, an intertrial interval ranging between 6 and 6.5 s was included (see Figure 4). Presentation order

of the stimuli and different durations were randomized. After completing the experiment, the participants were thoroughly debriefed about the purpose of the experiment and thanked. The experiment was run using E-Prime® 2.0 (Schneider et al., 2002) and was presented on a 31" display at a resolution of $2,400 \times 1,200$ pixels and a refresh rate of 60 Hz.

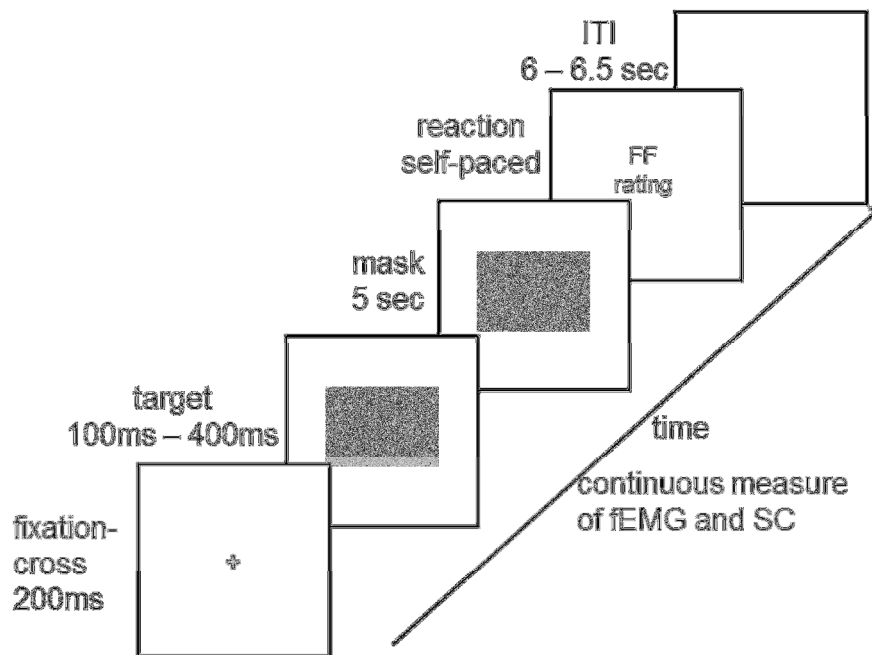


Figure 4. Sequence of a trial in Experiment 2. FF: felt fluency; ITI: Inter-trial interval.

Physiological data preparation and analysis. Both fEMG and SC were recorded with 2,048 Hz and filtered online with a 500 Hz low-pass filter. The data were then stored on hard-drives and were later pre-processed offline. All data pre-processing was performed in Matlab 7.14 (MathWorks Inc., USA) using the EEGLAB toolbox (Version 13.0.0, Delorme & Makeig, 2004)(Version 13.0, REF) for fEMG and the Ledalab toolbox (Version 3.4.7, Benedek & Kaernbach, 2010a, 2010b) for SC. For further analysis the fEMG and the SC data were split up in two separate files to facilitate processing.

The fEMG signal was filtered with a 20 Hz high-pass filter to reduce blink artefacts (van Boxtel, 2001) and a 45 to 55 Hz notch-filter to reduce power line artefacts. Both filters were applied with an updated filtering function in EEGLAB (`pop_eegfiltnew()`, see Widmann & Schröger, 2012). Then the signal was rectified and filtered with a moving average filter

(size: 125ms, see also Topolinski et al., 2009). Next, the signal was cut into trials and baseline corrected. For the baseline we chose 1 s prior to the fixation cross (1,200 ms to 200 ms prior to the stimulus). Thus the signal now reflected the change in activation from the baseline. This signal was then inspected for artefacts by comparing the activation in the data with video recordings. All instances where activation was due to movement unrelated to the actual task (such as chewing, scratching, or touching the electrodes) were removed from the data. After artefact coding, data from one participant had to be removed from further analysis, because less than five trials remained in three of the four conditions (maximum per condition is 25). In a final step the data were *z*-transformed per muscle region and participant (Bush, Hess, & Wolford, 1993; Gerger, Leder, & Kremer, 2014; Winkielman & Cacioppo, 2001). To test how the fEMG signal develops over time the data were separately averaged for each of the five seconds following the stimulus per each condition, muscle region, and participant.

The SC signal was first filtered with a 45 to 55 Hz notch-filter to reduce power line artefacts. As the SC response is slower than the fEMG response (Dawson et al., 2000), the amount of data was reduced by first applying a 10 Hz low-pass filter and then down sampling the signal to 32 Hz. Next, the signal of each participant was visually inspected for artefacts. Data from one participant had to be removed due to a high number of artefacts and signal losses. Data from the remaining participants was then further processed using the Ledalab toolbox (Version 3.4.7, Benedek & Kaernbach, 2010a, 2010b). Here, the signal was first smoothed with a Gaussian filter (16 Hz). To separate the tonic SC activation, which slowly fluctuates over time, from the stimulus dependent phasic activation, continuous decomposition analysis (CDA, Benedek & Kaernbach, 2010a) was performed. As the SC signal is comparably slow, the sum of all activation exceeding an amplitude of at least 0.01 μ S starting from the end of the first second to the fifth second (thus, four seconds in total) after stimulus offset was computed separately for each trial (following the guidelines of the Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures,

2012). The data were then z -transformed within participant. cursory inspection of the data revealed a few trials where the z -transformed conductance was much higher than in all other trials. To correct for such outliers, we removed all trials in which the z -transformed conductance exceeded the mean conductance ± 3 standard deviations (calculated separately for each participant). After removing these outliers (2.4% of all cases) the remaining trials were averaged per condition and participant in IBM SPSS Statistics 20.

Results and Discussion

Behavioral data. To analyse how variations in ease of processing influence the reported feeling of fluency we performed a one-way repeated measures ANOVA with ease of processing (presentation duration of 100, 200, 300, or 400 ms) as the factor and the ratings of felt fluency (inverted, see above) as dependent variable. Replicating Experiment 1, we found a significant main effect of ease of processing, $F(1.87, 46.63) = 23.48, p < .001, \eta_p^2 = .48$ (see also Figure 3). Post-hoc pairwise comparisons showed significant differences among all presentation durations ($ps < .007$), except 300 versus 400 ms ($p > .99$)⁵. These results show that slightly adapting the trial procedure and measuring physiological data did not harm the effect of ease of processing on feelings of fluency. At least from 100 to 300 ms felt fluency increased with longer presentation durations.

fEMG data. To analyse whether higher ease of processing leads to more positive affective reactions we performed two repeated measures ANOVAs, one for the M. corrugator supercilii region and one for the M. zygomaticus major region. As we were interested how the effects change over time the five seconds after the stimulus presentation and prior to the response were binned in five 1-second segments. This resulted in two 4 (ease of processing, 100, 200, 300, or 400 ms) $\times 5$ (time segment 1-5) ANOVAs with the mean z -transformed activation over the muscle region as dependent variable. The original unit of fEMG activation is millivolt (mV). Due to z -transformation the resulting values are not interpretable as

activation in mV; the direction of effects, however, remains the same: the higher the value the higher the activation, and vice versa.

For the *M. corrugator supercilii* we found a significant main effect of ease of processing, $F(3, 72) = 3.25, p < .027, \eta_p^2 = .12$, a significant main effect of time segment, $F(2.02, 48.46) = 4.35, p = .018, \eta_p^2 = .15$, but no interaction, $F(12, 288) = 1.61, p = .09, \eta_p^2 = .06$. Post-hoc pairwise comparisons indicated an inhibition of the corrugator activation at higher compared to lower ease of processing. The comparison between 100 and 400 ms showed a trend ($p = .074$, all other comparisons, $ps > .148$). For the time segments we found a lower activation in the first segment ($M = -0.34, SD = 0.4$) than in the fourth segment ($M = 0.10, SD = 0.4, p = .005$).

For the *M. zygomaticus major* we found a significant main effect of time segment, $F(2.16, 51.89) = 38.42, p < .001, \eta_p^2 = .62$, but no effects of ease of processing, $F(3, 72) = 1.20, p = .317, \eta_p^2 = .05$, and no interaction, $F(3.70, 88.85) = 0.69, p = .591, \eta_p^2 = .03$. Post-hoc pairwise comparisons showed that zygomaticus activations in seconds 1 and 2 were significantly higher than in seconds 3, 4, and 5 ($ps < .002$).

The pattern of fEMG results indicated that in our experiment higher ease of processing was only reflected in an inhibition of the *M. corrugator supercilii* region that hints at a slightly positive affect (see also Topolinski et al., 2009). Nonetheless, the activation of the *M. zygomaticus major* region, which should also have indicated this positive affect, was not influenced. Regarding the time segments, the data pattern showed that corrugator activation increased while zygomaticus activation decreased. Over the duration of a trial, participants exhibited increased negative affective reactions. This could be due to presenting mildly affective stimuli for very short durations in combination with rather long intervals between the stimulus and the response and between trials. However, the recording of the fEMG and SC signal necessitated these intervals. If the participants reacted with negative affect to the

increased intervals, this effect could have built up across the segments and might have overshadowed the subtle effects of feelings of fluency. To tackle this issue we also analysed only the first time segment—the first second of the recordings.

For the corrugator a one-way ANOVA (ease of processing, 100, 200, 300, or 400 ms) with the mean z-transformed activation over the muscle region in the first second as dependent variable showed a main effect of ease of processing, $F(3, 72) = 3.16, p = .030, \eta_p^2 = .12$. As before, activation tended to decrease over time (see Figure 5). For the zygomaticus the ANOVA again showed no main effect of ease of processing, $F(3, 72) = 0.56, p = .644, \eta_p^2 = .02$.

To sum up, the only indication for an increased positive affect due to higher ease of processing (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001) was a slight inhibition of the M. corrugator region with longer presentation duration of the stimuli, and consequently higher ease of processing. The activation of the M. zygomaticus region remained largely uninfluenced by our manipulation.

SC data. To analyse whether higher ease of processing leads to a higher unspecific activation we performed a repeated measures ANOVA with ease of processing (presentation duration of 100, 200, 300, or 400 ms) as a factor and the summed z-transformed SC activation poststimulus (seconds 1 to 5) as the dependent variable. The original unit of SC activation is microsiemens (μS). (Siemens is the SI unit of electrical conductance.) Due to z-transformation the resulting values are not interpretable as conductance in μS ; the direction of effects, however, remains the same: the higher the conductance the higher the activation, and vice versa.

The ANOVA showed a main effect of ease of processing, $F(3, 72) = 8.55, p < .001, \eta_p^2 = .26$. Contrary to our prediction, the conductance at higher ease of processing was

significantly lower compared to lower ease of processing. The conductance at 100 ms ($M = -.01$, $SD = 0.14$) and at 300 ms ($M = -0.09$, $SD = 0.11$) was significantly higher than at 400 ms ($M = -0.21$, $SD = 0.12$, $p < .038$, see Figure 6). Thus, in our case higher ease of processing did not come along with higher, but lower, unspecific activation.

Morris et al. (2008) found that feelings of familiarity were reflected in longer SCR latencies. We thus also analysed how the latency of the skin conductance was affected by ease of processing in an ANOVA, with ease of processing (presentation duration of 100, 200, 300, or 400 ms) as a factor and the latency of the first SCR (exceeding the threshold of $0.01 \mu S$ within the window of seconds 1 to 5 post-stimulus) as the dependent variable. The ANOVA showed no effect of ease of processing on the latencies, $F(1.98, 47.44) = 0.66$, $p = .522$, $\eta_p^2 = .03$.

For the sake of completeness and parallel to the fEMG analysis, we also analysed the SCRs in the first second. Due to the slow response of skin conductance (Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012) we chose Second 2 post stimulus as the equivalent of Second 1 in the fEMG analysis. The results were similar to the analyses above. We still found a significant, albeit weaker, main effect of ease of processing on the summed z-transformed SC activation, $F(3, 72) = 2.98$, $p = .037$, $\eta_p^2 = .11$. This is in line with the fact that it takes some time for the SCR to unfold and with the suggestion to analyse a response window of four seconds post stimulus starting at the first second (Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012). Also the latencies of the first SCR exceeding the threshold did not significantly vary with ease of processing, $F(2.38, 57.16) = 1.24$, $p = .301$, $\eta_p^2 = .05$.

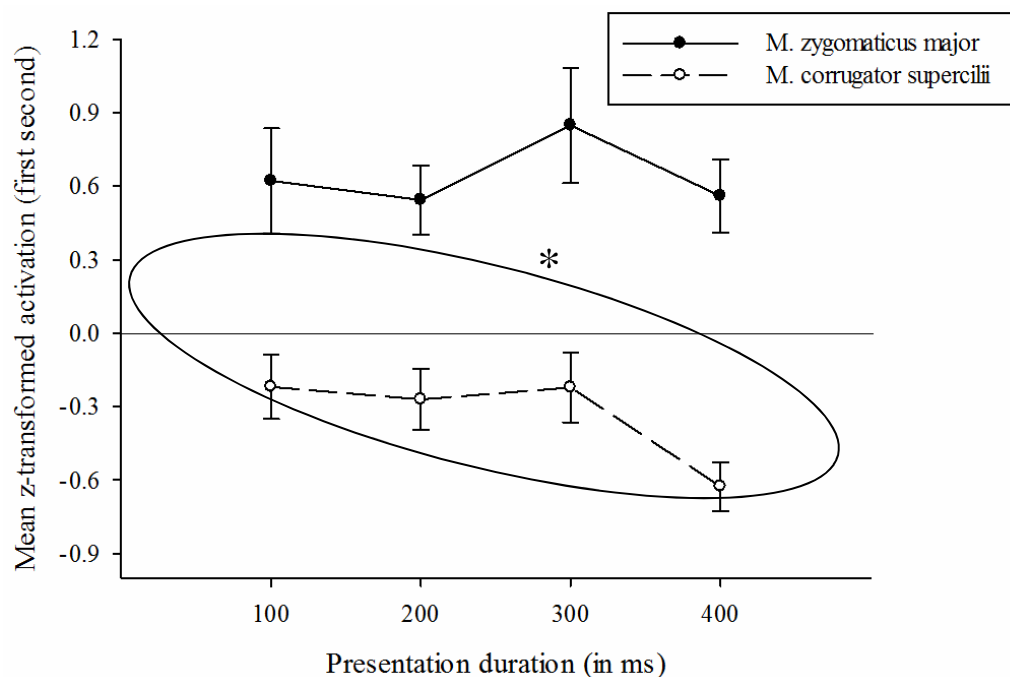


Figure 5. Mean z-transformed activation of the first second over the M. zygomaticus major region (solid line) and the M. corrugator supercilii region (dashed line) in Experiment 2. Error bars represent standard errors of the mean.

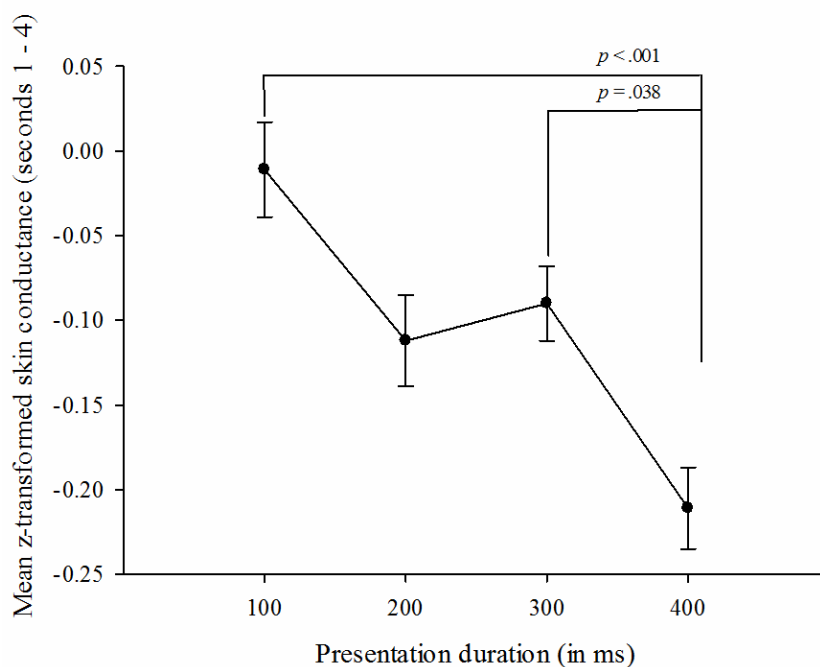


Figure 6. Mean z-transformed skin conductance during Seconds 1 to 4 in Experiment 2. Error bars represent standard errors of the mean.

General Discussion

In two experiments we tested effects of variations in ease of processing on feelings of fluency and on affective responses. Theories on processing fluency suggest that the feeling of fluency is either affectively positive (Winkielman et al., 2003) or an unspecific activation (Bornstein & D'Agostino, 1994). Our results on a behavioural level show that higher ease of processing indeed leads to higher feelings of fluency and a more positive evaluation of the stimulus. On the one hand, this was indicated by higher stimulus valence ratings, but no higher stimulus arousal ratings. On the other hand, the effects of ease of processing on the perceivers' feelings showed a different pattern. Although higher feelings of fluency were reported, participants only gave higher felt arousal ratings, but not more positive valence ratings. On a physiological level, tested in Experiment 2, we found only little evidence for physiological correlates of the effects. In line with Experiment 1, reported feelings of fluency increased with longer presentation durations. The notion that the feeling of fluency is affectively positive (Winkielman et al., 2003) could be shown in a slight inhibition of the frowning muscle region. A decrease in SC responses with higher ease of processing, however, was even in contrast to the notion that feelings of fluency led to an unspecific activation (Bornstein & D'Agostino, 1994).

The behavioural findings supported both theories. Experiment 1 extends previous research by showing that the validity of the different theories depends on the target of the ratings. When evaluating a stimulus, felt fluency elicited by that stimulus leads to a more positive evaluation of that stimulus. This finding is in line with the hedonic marking of fluency. However, when a more object-detached personal feeling of fluency has to be evaluated, felt fluency, elicited by a stimulus, is not evaluated as something positive in valence, but results in an unspecific arousal. It could thus be argued that the feeling of fluency per se is an unspecific activation which, in combination with a stimulus, is of positive

valence. This might be due to the fact that the unspecific activation is misinterpreted as a positive affective response towards the stimulus (Dutton & Aron, 1974). Together with the absence of an effect on stimulus arousal, this finding supports the hypothesis that—at least when rating a stimulus—processing fluency is mainly characterized by positive feeling dimensions (see Exp. 2 in Reber et al., 1998). The findings of Mandler et al. (1987), showing that even evaluations of brightness and darkness are influenced by higher ease of processing, are, however, inconsistent with this hypothesis. At this point we can only speculate about the underlying causes. One possible explanation might be the context of the experiment. Previous research has shown that the context also influences the interpretation of fluency (Unkelbach, 2007). On the one hand, in the experiments of Mandler et al. (1987) stimuli were presented very briefly (1 or 2 ms). Therefore, participants might have been in a state of high uncertainty or even bad mood due to not seeing the stimuli. This could have produced the nonspecific effects in the evaluations of the stimuli. However, Albrecht and Carbon (2014, Exp. 2) could show that even when the stimuli were clearly visible, nonspecific effects occurred. Also, in Experiment 2 of Reber et al. (1998) as well as in our experiment stimuli were always visible. Here, participants maybe had no reason to relate the feeling of fluency to a “non-positive” stimulus evaluation. This explanation, however, remains to be further tested.

Our manipulation of processing fluency (based on varying the presentation durations) is different from mere exposure manipulations (for a review see Bornstein, 1989) in which the higher ease of processing originates from stimulus repetition. In Experiment 1 ratings of stimuli on the feeling dimension were higher when tested in the second block, indicating a mere exposure effect. However, this effect did not interact with the effects due to other variations in ease of processing. Thus, the reported effects of higher ease of processing on evaluations cannot simply be explained by mere exposure or higher familiarity.

In Experiment 2, we could replicate the effects of ease of processing on felt fluency ratings from Experiment 1. Higher ease of processing was reflected in reports of higher felt fluency. In regard to the conflicting accounts of the nature of felt fluency, the physiological responses in terms of facial electromyography (fEMG) and skin conductance (SC) were by trend in favour of the hedonic marking of fluency. Responses of fEMG which capture positive or negative affect showed a slight positive reaction as indicated by inhibitions of the M. corrugator supercilii region (Topolinski et al., 2009). An activation of the M. zygomaticus major indicative of positive affect (Winkielman & Cacioppo, 2001) could not be found. Possibly, the effects were too subtle to be reflected in the activation of this muscle region.

The notion that fluency is experienced as an unspecific activation in our Experiment 2 could not be confirmed. Measures of skin conductance indicated that higher ease of processing came along with lower skin conductance, and thus, if anything, with lower activation. This effect is in line with previous research showing that skin conductance responses are especially sensitive to novel, and thus disfluent, material (see Dawson et al., 2000, for an overview). This post-hoc interpretation makes clear that in comparison to the verbal reports, the physiological measurements could be too unspecific to allow any firm conclusions.

Together the findings from both experiments showed that stimulus evaluations became more positive with higher ease of processing, as indicated by higher ratings and, less strongly, by the inhibition of the frowning muscle. This is in line with the notion that processing fluency is hedonically marked (Winkielman et al., 2003). In contrast to the notion that processing fluency is an unspecific activation we could not find effects in stimulus arousal ratings or physiological indices of arousal. Regarding the effects on the personal feelings of the participants, effects of higher ease of processing found in Experiment 1 were not confirmed by higher SCRs in Experiment 2. These subtle effects of ease of processing on

positive physiological responses did thus not translate into self-reports of ease of processing, too. The latter finding might be due to the fact that the physiological responses were reflecting processes that were entirely unrelated to the required judgments (of ease of processing). This finding would also show a drawback of the measure of physiological responses without accompanying self-reports: If the two dissociate, it is difficult to relate them to one another because of a lack of emotion-specificity of the physiological responses.

However, this leaves open the question where the effects of ease of processing on reported feelings of arousal in Experiment 1 come from? As the term “cognitive feelings” already suggests (Greifeneder, Bless, & Pham, 2011), the arousal judgments might have also reflected “cold cognitions” without much physiological underpinnings – that is, a cognitive bias towards arousal judgments. It is also possible that experiences of ease of processing are not themselves felt as affective responses, but rather as cognitive cues for human evaluations.

We can only speculate why variations in ease of processing in Experiment 2 were only weakly reflected in physiological responses. Of course, measuring physiological indices parallel to self-reports of arousal and valence would have allowed more valid conclusions on the relationship between felt fluency and affect. Also, in contrast to previous studies applying fEMG in research on processing fluency (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001), we did not explicitly ask for liking but for felt fluency. One could argue that when participants evaluate liking or affective responses to an object then stronger physiological responses might occur. This follows from the fact that the participants’ task-specific foci of attention on non-evaluative aspects of the stimuli could have distracted the participants from their affective responses. In other words, implicit measures in general and physiological responses in particular are subject to context effects, such as the task at hand (Wittenbrink & Schwarz, 2007).

One limitation of our findings concerns the stimuli. To elicit stronger affective responses, stimulus material having stronger emotional content might be warranted. We refrained from using this material in the present study for two main reasons. First, strong emotional content might override relatively subtle effects of ease of processing. And second, using similar material to previous studies (Forster et al., 2013; Reber et al., 1998; Winkielman & Cacioppo, 2001) helps in better understanding the effects from the previous studies by avoiding the confound of different stimulus material.

To sum up, our findings show that the feeling of fluency contributes to a positive evaluation of the stimulus, as reflected in more positive evaluations and a subtle physiological response. This response, however, did not lead to more positive feelings in the perceiver. Thus, in line with the feelings-as-information account (Schwarz, 2011), feelings of fluency can be a powerful source of positive evaluations of objects, but not of the own feeling.

Footnotes:

- 1) From the literature there is no indication that the terms “processing fluency” and “ease of processing” denote two distinct processes. Here, we use “ease of processing” to describe the process of fluency and “processing fluency” when referring to the theory.
- 2) The respective questions in the experiment were: for stimulus valence (“Wie positiv/negativ ist dieses Bild?” [“How positive/negative is the image?”]), for stimulus arousal (“Wie stark aktiviert dieses Bild?” [“How arousing is the image?”]), for felt valence (“Welche Stimmung löst die Wahrnehmung des Bilds aus?” [“In which mood does the perception of the image set you?”]) and for felt arousal (“Wie stark aktiviert Sie die Wahrnehmung dieses Bilds?” [“How strongly do you get aroused by the perception of this image?”]).
- 3) We thank the reviewer for pointing that out.
- 4) Mind that the scale anchoring is reversed to Experiment 1. Informal post-questions in Experiment 1 indicated that the anchoring from 1 (*very easy*) to 7 (*very hard*) is more intuitive. For data analysis the felt fluency rating scale was inverted to simplify the interpretation. Higher ratings consequently represent higher felt fluency. As can be seen in the results section, the change in scale anchoring did not affect the results.
- 5) In the preprocessing of the fEMG and SC signals, data from two participants (one in each signal) had to be excluded from further analysis. We thus ran the analysis of the felt fluency ratings also without those two participants. The results did not change. We report the analysis of the full sample of participants.

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Summary & Outlook

In this paper we tested the affective nature of felt fluency. In behavioral and physiological measurements of the two core dimensions of affect, valence and arousal (Russell, 1980, 2003), we showed that feelings of fluency are not strongly reflected in physiological indices.

In Experiment 1, higher ease-of-processing influenced ratings of the feeling of fluency, and also led to higher stimulus valence ratings. Furthermore, participants rated their own arousal more highly. Stimulus arousal ratings and the participants' own valence ratings remained uninfluenced by higher ease-of-processing. In other words, the more fluent the processing, the more positive the object was rated and the more aroused was the perceiver.

In Experiment 2, these findings were further explored by measuring physiological indicators of valence (fEMG) and arousal (SC). The findings provided only partial support of the conclusions from Experiment 1. A slight decrease in activation of the frowning muscle by trend backed the positive stimulus ratings from Experiment 1. However, the smiling muscle, the main indicator of positive affect, was not influenced. Furthermore, the higher feelings of arousal were not reflected in higher skin conductance activity. Our results rather show that skin conductance decreased with higher ease-of-processing.

What do the results tell us regarding the two divergent accounts on processing fluency—the perceptual fluency/attributional account (Bornstein & D'Agostino, 1992, 1994) describing fluency as a *neutral* and *affectively unspecific* activation, and the hedonic marking of fluency (Reber, Schwarz, et al., 2004; Winkielman et al., 2003) describing fluency as being *positive* per se? Experiment 1 indicates that interpretation depends on whether a stimulus or the personal feeling is evaluated. In line with the hedonic marking of fluency, stimuli were rated more positively with higher ease-of-processing. On the other hand, higher feelings of

arousal are rather in line with the perceptual fluency/attributional account. However, Experiment 2 only showed a trend suggesting that experiencing fluency is positive (slight decrease in activation of the frowning muscle).

What could be the reasons for these findings? It is possible that the effects were too subtle for the physiological measurements, but nonetheless exerted their influence on ratings in Experiment 1. Another possibility is that feelings of fluency, although called “feelings,” are not affective per se. As the term “cognitive feelings” already suggests (Greifeneder et al., 2011), experiencing ease of processing might not be an affective, but rather a cognitive cue for our evaluations. This interpretation is, however, not backed by previous findings on physiological responses to higher ease-of-processing (Gerger et al., 2011; Topolinski et al., 2009; Winkielman & Cacioppo, 2001).

5) Image Ambiguity and Fluency

Introduction

In this paper, published in PLoS ONE, we addressed the contradiction between processing fluency accounts and accounts in the psychology of art with regard to ambiguous images. In the fine arts, ambiguity in images is seen as a source of pleasure (Gamboni, 2002; Leder et al., 2004). The challenges posed by ambiguous art (i.e., explicitly intended conceptual disfluency) is often argued to be what makes art exciting and interesting (Bulot & Reber, 2012). However, according to processing fluency accounts, ambiguous and unclear images, which are by definition difficult to process, should not be preferred (e.g., Reber, Schwarz, et al., 2004). From an experimental psychology standpoint as well, ambiguity should in general be disliked and/or avoided (Blanchard, Griebel, Pobbe, & Blanchard, 2011; Curley, Yates, & Abrams, 1986; Ellsberg, 1961; Hock & Krohne, 2004).

One important difference between ambiguity in the arts and in everyday life is the time we can invest to endure or solve the ambiguity. In the arts we can take our time in front of an ambiguous artwork, often without external danger that may accompany non-fluent processing or resolution. In everyday life on the other hand, when for example deciphering road signs, we need to make correct decisions quickly. Thus, in a series of experiments we tested the time course of classification of ambiguous material. Second, we tested how appreciation, interest, and feelings of fluency in regard to ambiguous material varied with time. As ambiguous material, we selected a number of paintings by the 19-20th century Belgian surrealist painter René Magritte. His artworks are figurative, thus objects are easy to perceive already at short presentation durations. Nonetheless, the meaning of the works is often ambiguous, because the semantic and syntactic relations of the objects are inconsistent. To create non-ambiguous counterparts, we manipulated the Magritte paintings in Adobe

Photoshop[®] rendering them visually and conceptually less ambiguous (see Figure 1 for illustrations). To make the distinction between ambiguous and non-ambiguous paintings less obvious, in the final experiments we also added paintings from other artists. Those paintings also varied in ambiguity.

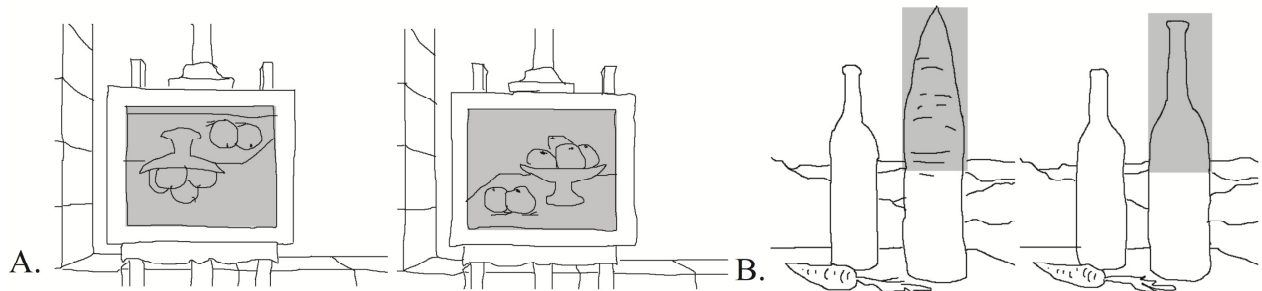


Figure 1: Two illustration (A and B) of the image manipulations, in both A and B the left image represent the original version by Magritte and the right image the manipulated version. The location of the manipulation is highlighted in grey. Illustration by M. Jakesch.

In the first series of experiments we tested (a) at which presentation duration (10, 50, 100 or 500 ms) ambiguity can be detected above chance level (d' scores from signal detection theory, Macmillan & Creelman, 2005), and (b) whether the reaction times in classifying ambiguous and non-ambiguous images significantly differed. Regarding (a), we first expected that performance in ambiguity detection increases with longer presentation durations. According to previous research, whether two artworks have a similar content can be successfully detected already at 10ms presentation duration (Augustin, Leder, Hutzler, & Carbon, 2008). Basic object discrimination is possible at around 20ms (VanRullen & Thorpe, 2001a, 2001b). Thus, given the complexity of ambiguity evaluation in combination with artworks as stimuli we expected that at least at 50ms ambiguity detection performance is above chance. Regarding (b), conflicting accounts preclude straightforward predictions. Findings in language research (Gottlob, Goldinger, Stone, & Van Orden, 1999; Piercey & Joordens, 2000) and processing fluency (Oppenheimer, 2008; Reber, Wurtz, et al., 2004) would suggest that ambiguity takes longer to be detected. Whereas theories on scene recognition would suggest that elements that do not fit in a scene, so called semantic scene

violations, such as a coffee machine in a scene of a barn, are detected faster than elements that fit in a scene (Becker, Pashler, & Lubin, 2007; Underwood, Templeman, Lamming, & Foulsham, 2008).

In a second series of experiments we tested whether manipulations of perceptual fluency (presentation durations of 10 ms vs 50 ms [Exp. 2a], 10 vs 100 ms [Exp 2b], 10 vs 500ms [Exp 2c], and 100ms vs 1000ms [Exp 3]) and manipulations of conceptual fluency (ambiguous vs. non-ambiguous stimuli) influence the aesthetic appreciation (in terms of liking and interest). We expected that the longer the stimuli were presented the more they were liked, regardless of ambiguity. For the ambiguity, however, we expected that at longer durations the ambiguous artworks, which are low in conceptual fluency, might be preferred and might be found more interesting, as higher-order processes overwrite effects of fluency (Graf & Landwehr, 2015; Leder et al., 2004). It is furthermore possible that at longer presentation durations ambiguous material is also found more fluent and thus preferred. To test this possibility we also measured felt fluency (Forster et al., 2013).

Image Ambiguity and Fluency

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Abstract

Ambiguity is often associated with negative affective responses, and enjoying ambiguity seems restricted to only a few situations, such as experiencing art. Nevertheless, theories of judgment formation, especially the "processing fluency account", suggest that easy-to-process (non-ambiguous) stimuli are processed faster and are therefore preferred to (ambiguous) stimuli, which are hard to process. In a series of six experiments, we investigated these contrasting approaches by manipulating fluency (presentation duration: 10ms, 50ms, 100ms, 500ms, 1000ms) and testing effects of ambiguity (ambiguous versus non-ambiguous pictures of paintings) on classification performance (Part A; speed and accuracy) and aesthetic appreciation (Part B; liking and interest). As indicated by signal detection analyses, classification accuracy increased with presentation duration (Exp. 1a), but we found no effects of ambiguity on classification speed (Exp. 1b). Fifty percent of the participants were able to successfully classify ambiguous content at a presentation duration of 100 ms, and at 500ms even 75% performed above chance level. Ambiguous artworks were found more interesting (in conditions 50ms to 1000ms) and were preferred over non-ambiguous stimuli at 500ms and 1000ms (Exp. 2a - 2c, 3). Importantly, ambiguous images were nonetheless rated significantly harder to process as non-ambiguous images. These results suggest that ambiguity is an essential ingredient in art appreciation even though or maybe *because* it is harder to process.

Citation: Jakesch M, Leder H, Forster M (2013) Image Ambiguity and Fluency. PLoS ONE 8(9): e74084. doi:10.1371/journal.pone.0074084

Editor: Maurice J. Chacron, McGill University, Canada

Received: May 14, 2013; **Accepted:** July 25, 2013; **Published:** September 5, 2013

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Funding: This research was supported by the Austrian Science Fond (FWF). Project Number: P23538-G21. <http://www.fwf.ac.at>. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

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Introduction

In our everyday lives we are often confronted with ambiguous information, coming from manifold sources and present in various sensory domains. At early processing stages, sensory ambiguities challenge the visual system. At higher-order levels of processing, where the sensory percept is no longer ambiguous, equivocal interpretation or multiple solutions characterize objects of cognitive ambiguity. For example, in the domain of fine arts, sensory ambiguities emerge when it is unclear whether a dark area is part of an object or a shadow. Cognitive ambiguities are often found in surrealist paintings when painted objects are combined into dream-like scenes.

There is something particularly interesting about the responses to ambiguity in art. The visual fine arts are a domain for which ambiguity was not only discussed as an essential feature but also as a source of pleasurable aesthetic experiences [1–3]. However, this seems to contradict those theories about formation of preference that claim that easy-to-process (fluent) stimuli are most preferred [4–7]. Therefore, ambiguous images which are harder to interpret should be preferred less than non-ambiguous counterparts. Using reproductions of surrealist artworks and modified,

manipulated versions the present study aims to investigate which of these contrasting theories explain aesthetic judgments for ambiguous and non-ambiguous artistic images.

Research on fluency effects has indicated that the longer something is presented, the more easily it can be processed e.g. [8,9]. However, it is an open issue how long it takes to successfully classify conceptual ambiguity in images. In order to understand how fluency and ambiguity – as features of artworks – affect liking, we first studied how and when ambiguity is processed and classified in surrealist artworks (Part A). Based on these findings, experiments (Part B) regarding the controversial predictions by current theories in psychology were run: is ambiguity in fine art preferred even though it should be harder to process? Please see Figure 1 for an overview of research questions and experiments.

So far, ambiguity in pictures was mostly studied by means of multi-stable images like Escher figures. Ambiguity has been investigated more frequently in other domains, such as in language processing, social relations and decision making. Therefore, in order to clarify the concept of ambiguity employed in the present studies, different types of ambiguity are discussed in more detail in the following section. Then we provide a short review regarding responses to ambiguous stimuli in classification and appreciation.

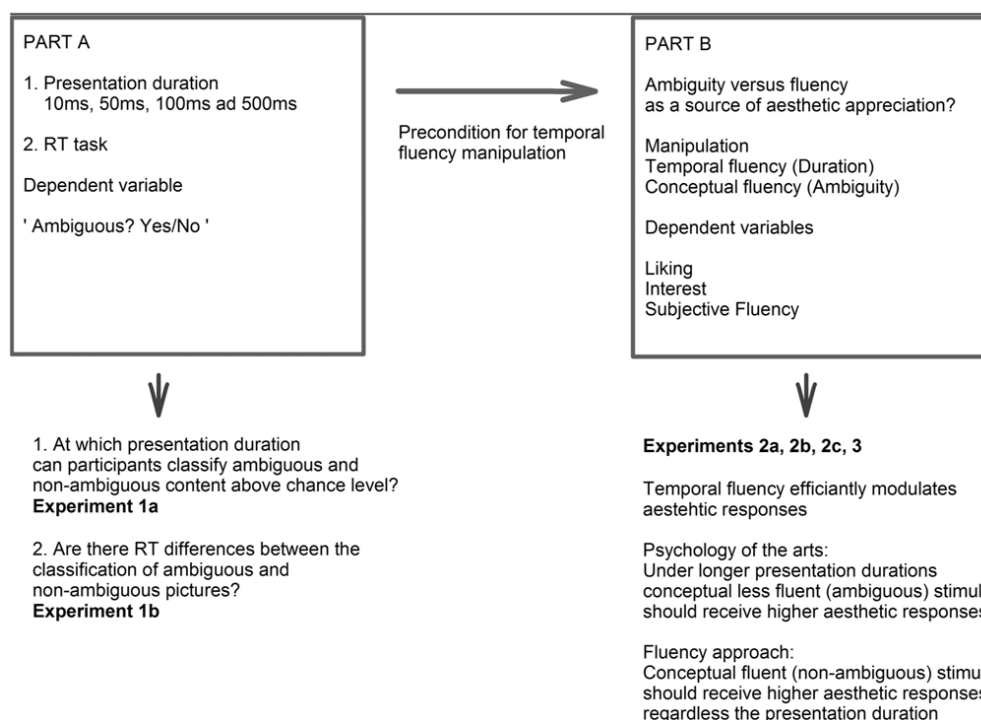


Figure 1. Overview of research questions and experiments.

doi: 10.1371/journal.pone.0074084.g001

Types of ambiguity

Sensory ambiguity. From a vision science perspective it can be argued that the light pattern falling on the retina is generally ambiguous – see 10 for a review – and therefore a challenge for the visual system [11]. Such sensory ambiguous input is encoded by the brain by comparing the input with internal representations. The speed of this comparison depends on the percept and its level of ambiguity but also on the readiness of individuals to impose internal representations [12–14]. At an early stage of processing, familiar interpretations are dominant. Prolonged viewing time then enables alternative (unfamiliar) interpretation(s) [14]. Thus, previous experiences foster the resolution of an ambiguous input [15,16].

Multi-stable or reversible images can reveal insights in processes of sensory ambiguity. These images are characterized by one physical percept that can have at least two different visual experiences. These experiences are reversible ("flip" over time) and cannot be fully controlled by observers. Even though it has been shown that people were able to concentrate on one of the two visual experiences and "hold" it to a significant degree, it was not possible to fully eliminate reversals [10]. The authors assumed that perceptual,

bottom-up factors like the early initiation of reversal at ~120 ms but also top-down processes like expectations, learning or contextual information modulate the oscillation rate of multi-stable images. Multi-stability and other sensory ambiguities are playfully used in visual arts. Interestingly, everyday life perception and art perception might differ. In a review, Mamassian [17] argued that prior experience or knowledge is used in everyday life settings whereas conventions are used in visual arts to resolve ambiguity. Even though some of these conventions stem from prior everyday life experiences, others differ to a certain extent like color contrast exaggerations or mirror depictions of figures [17].

Cognitive ambiguity. Cognitive ambiguity arises when a stable percept elicits only one visual experience but more than one meaning or interpretation. For example, when a word has more than one meaning – either in spelling, in pronunciation, or both e.g. [18,19]. For example, the word "bat" can stand for a sports gear but also for an animal. In such kinds of homonymous words the alternatives in meaning are usually unrelated. In polysemous words, on the other hand, one word is associated with multiple related metaphorical interpretations, like in "twisting the ankle" or "twisting the truth" [20]. In other

domains, cognitive ambiguity can arise from ambiguous facial expression e.g. [21,22], from role confusion regarding job position e.g. [23] or from insufficient information in decision making e.g. [24]. To summarize, ambiguity arises based on sensory and/or cognitive processes and in various domains. In the following section responses to various ambiguous stimuli are discussed in respect to different types of ambiguity and our hypotheses.

Responses to ambiguous stimuli: Classifying ambiguous and non-ambiguous content

Why is detecting and classifying ambiguity relevant? Successfully encoding the environment enables organisms to plan, trigger, and execute appropriate actions; to respond or react to events, stimuli, or people. For example, in the case of dangerous, threatening events resolving ambiguity can even be relevant for survival. If there is not enough, unclear, or ambiguous information, the probability to fail in situations and tasks is increased [25,26]. Thus, Epstein [27] assumed that ambiguity per se would evoke threat and negative emotions. Accordingly, people report lower job satisfaction under higher role ambiguity [23,28], are less efficient [29] and respond with more stress [30]. Further, ambiguity in decision making causes avoidance behavior [31,32]. These examples have in common that ambiguity diminishes successful encoding and processing, and as a consequence, makes it harder to appropriately react to events. All examples are therefore in accordance with a "processing fluency" explanation that hard-to-process situations are negatively connoted, and disliked. Consequently, when confronted with easy to perceive stimuli people feel more confident [33]. This subjective ease of processing is experienced positively and is an important meta-cognitive cue in the formation of human judgments [34,35]. Processing fluency has been shown to influence a variety of responses like reaction times e.g. [4,36], preferences e.g. [4–7], confidence e.g. [33,37], feel of familiarity e.g. [38–40] or truth e.g. [41–43]. Fluency studies often used words/linguistic stimuli [39,40,42,43]. Statements presented in fluent rhyming and prosody were rated as being more true [42,43]. More regular [40] or semantically primed words [8] were rated as more familiar. Because high fluency is associated per definition with high speed and accuracy and low resource demands, it can be assumed that disfluent stimuli are perceived and classified slower than fluent ones [4,36]. Hence, recognizing and processing ambiguous stimuli should take longer. Interestingly, this assumption was supported only for specific tasks. In visual lexical decision tasks (classification as a word or a non-word), several studies found faster reaction times and faster word recognition for ambiguous words (isolated, without context) than for unambiguous words e.g. [44–46]. This "ambiguity advantage effect" was found for polysemous (more than one sense) but not for homonymous words [44,45]. It has been hypothesized that the advantage of ambiguous words might be due to their multiple and rich representations [45,47]. Nevertheless, when a semantic classification task (interpretation of meaning e.g. are two words related?) was used, the reversed pattern was found. This "ambiguity disadvantage effect" – slower responses for ambiguous words – was

attributed to the more demanding meaning activation process [48–50] or, alternatively, to the decision making process during semantic tasks [49]. Thus, in lexical decision tasks multiple and rich representations [45,47] of ambiguous words might enhance perceptual and cognitive fluency causing their fast classification. However, when semantic classifications are required, the more demanding process of meaning activation for ambiguous stimuli reduces the classification speed. Consequently, the fluency account would predict that disfluent, ambiguous stimuli are processed slower than fluent, non-ambiguous stimuli [4,36].

What can be predicted for perceiving and classifying ambiguity in images? The multi-stable images used in most previous studies are not suitable to measure classification performance due to their temporally reversal nature. Therefore, in the present studies, we used reproductions of Rene Magritte artworks, always in an ambiguous, and carefully produced non-ambiguous version. Due to the nature of surrealism [51], in Magritte's paintings semantically unrelated objects are placed in a scene context (semantic violations) or represent syntactic violations. Surrealistic art therefore is similar to metaphorical ambiguity in language [52] and comparable with those real-world scenes used to test object-scene inconsistencies. In this line of research, similar terms as in language processing are used: Inconsistencies were created by inserting a semantically implausible object in a scene context (semantic violation) or by changing the configuration of a scene structure (syntactic violations) like scene-related objects that are moved to unlikely places or floating in the air e.g. [53]. Studies employing eye-movements like those of Loftus and Mackworth [54], indicated that semantically not fitting objects were fixated immediately after stimulus onset and also were fixated longer than other, consistent, objects e.g. [55–57]. According to such a "semantic pop-out" in scenes containing semantic violations, ambiguous artworks might be classified faster than their non-ambiguous counterparts. However, according to the fluency account a reversed pattern would be predicted: Ambiguous artworks should demand more cognitive resources to be interpreted in an (individually) satisfying way than non-ambiguous versions, resulting in slower processing. Thus, it seems that responses to ambiguity are often negative, especially in the case of sensory ambiguity, in social situations or decision-making. Nevertheless, there are some examples for exceptions, where responses to ambiguity are definitely positive.

The present study

We present two series of experiments (Parts A and B) in which cognitive ambiguity was varied by using surrealistic artworks by Rene Magritte and non-ambiguous control artworks. Part A ("Classifying ambiguous and non-ambiguous content") is concerned with the classification performance for ambiguous and non-ambiguous pictures (Experiment 1a and 1b). Part B (Appreciation of Ambiguity) investigates the relationship between ambiguity/fluency and aesthetic judgments (liking, interest).

Part A: Classifying ambiguous and non-ambiguous content. In Part A we investigate the participants' performance in successfully classifying ambiguous or non-

ambiguous picture content (Experiment 1a) by varying four presentation durations (10ms, 50ms, 100ms, 500ms). The comparison of different times reveals, which presentation duration is sufficient to result in an above chance classification performance. In Experiment 1b we test whether similar results are obtained, when differences in reaction times (RT) instead of differences in presentation duration are analyzed. We expected increasing sensitivity values over the presentation durations (10ms < 50ms < 100ms < 500ms). The presentation durations (10ms, 50ms, 100ms, 500ms) were chosen with respect to previous findings. Short durations had been shown to be sufficient for a successful classification (above chance level) of objects in scenes or of scenes themselves. Categorizing photographs on a semantic dimensions (is it an animal or a vehicle?) presented for 20ms resulted in 94% correct responses [73,74]. Above chance performance was found for 27ms presented masked stimuli – even under dual-task conditions [75]. Augustin, Leder, Hutzler, and Carbon [76] showed that the similarity of artworks' contents can be successfully processed already at 10ms presentation duration. Thus, ten milliseconds were chosen as lower bound. In contrast to shorter presentation durations, participants started to report more semantic categories of viewed scenes between 40 and 67 ms [77]. Fifty milliseconds therefore were used as second presentation duration. The third level, one hundred milliseconds, was chosen according to Fei-Fei et al. [77] and Reber et al. [9] studies. The longest presentation duration of five hundred milliseconds is commonly used as baseline duration, as within this time most of natural scene content is perceived [78–80] and opposed to the shorter durations, a few saccades can be made [77]. The chosen presentation durations will be further used in Part B as manipulation of fluency e.g. [9].

A second question concerned the time needed to detect and to report ambiguity. Experiment 1b was planned to investigate reaction time (RT) differences for ambiguous versus non-ambiguous pictures. We expected that ambiguous pictures are either classified slower than non-ambiguous pictures, based on findings in language research [48,50] and the fluency account [4,36] or faster due to the studies of "semantic pop-out" in scenes containing semantic violations e.g. [55–57].

Part B: Appreciation of ambiguity. In Part B, we studied the effects of ambiguity and fluency on aesthetic appreciation (liking, interest). We decided to measure liking to compare previous fluency findings with our data and interest based on the art-historical statements, that simple art with an obvious message appears to be uninteresting [2,60–62]. Interest is characterized by two dimensions /appraisals: novelty/complexity and coping potential [81–86]. According to Silvia's appraisal theory, objects or events are interesting when unfamiliar, new and complex but comprehensible [82]. This appraisal structure overlaps with one of Csikszentmihalyi's [69] elements of optimal experience on page 49: "A challenging activity that requires skills". Further, felt fluency (subjective experience of fluency) was measured as control for the fluency manipulations similar to previous studies [8,36]. Two fluency manipulations were chosen: a) *duration* manipulation [8,9] and b) *ambiguity* as conceptual fluency manipulation (ambiguous

versus non-ambiguous pictures). The *duration* manipulation represents a "temporal perceptual" fluency manipulation whereas *ambiguity* represents a higher-order "conceptual" fluency [34]. We assume that effects based on the perceptual fluency manipulation (*duration*) show the proposed positive influence on aesthetic judgments, namely that aesthetic judgments for ambiguous and non-ambiguous judgments increase with the presentation duration. However, in the case of conceptual fluency (*ambiguity*), we expect contrary results modulated by the duration manipulation. Whereas the conceptual fluency manipulation might not influence the aesthetic judgments under short presentation durations, it should be a more prominent cue at longer presentation durations as previous results suggest that semantic processing starts between 40 and 67ms [77]. Bearing in mind that in this case real-world scenes were used (which we are exposed to more frequently than to art), we expect to find effects of *ambiguity* under longer presentation durations (100ms, 500ms). According to the fluency account, conceptually fluent pictures (non-ambiguous ones) should receive higher aesthetic judgments whereas the reversed pattern should be found when the conceptual fluency is overwritten by other higher-order processes [1–3,72,87,88].

General Method

All four experiments reported here were conducted in respect to the Declaration of Helsinki (revised 1983) and guidelines of the Faculty of Psychology, University of Vienna. According to the Austrian Universities Act 2002 (UG2002) which held at the time the experiments were carried out, only medical universities were required to appoint ethics committees for clinical tests, application of medical methods, and applied medical research. Furthermore, data were collected anonymously and no harming procedures were used. Therefore, ethical approval was not sought for the execution of this study. Written informed consent was given by all participants. Participants could withdraw at any time during the experiment without further consequences.

Procedure and apparatus

Participants were tested individually or in groups of two in a laboratory setting. E-Prime experimental software [89] was used to present the stimuli on screen and record responses (response keys; RTs). Participants sat about 60 cm away from 21-in CRT monitors with 100-Hz refresh rates. Stimuli on the screen subtended 10° × 15° (portrait format) or 15° × 10° (landscape format) of visual angle. Viewing distance (and head position) was kept constant by chin and forehead rests. Visual acuity and color vision (Ishihara color plates) were tested prior to the experiment. In all experiments a similar procedure was used: practice trials were implemented before the main experimental blocks. In the experiments for Part A (1a and 1b) a Cedrus Button Box device was used to assure millisecond precision in RTs. The experimental block was divided into two parts with separate practice trials beforehand as the key mapping (yes/no) was balanced across the experiments. In the experiments in Part A, 2 × 8 practice trials and 2 × 22 trials (14

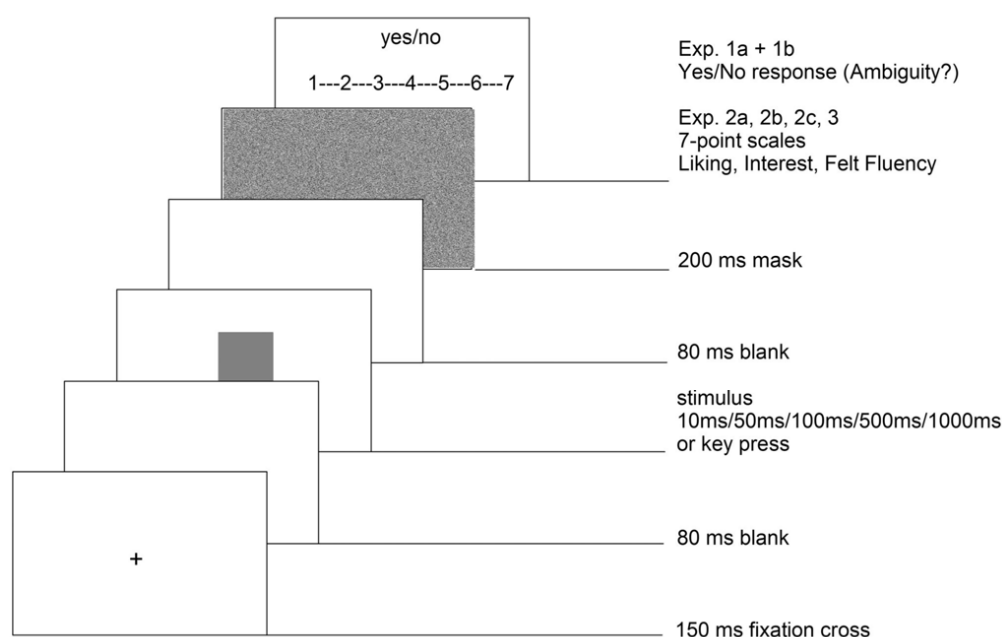


Figure 2. Schematic trial procedure.

doi: 10.1371/journal.pone.0074084.g002

target trials, 8 distractor trials) were run. In Part B, the keyboard was used to record responses on 7-point scales, therefore only one practice block was used in the beginning. After 12 practice trials, the main experimental block started with 56 trials (16 distractor pictures and 36 target trials). In both parts, in a second block all pictures were rated for familiarity on a 7-point scale ranging from 1(not familiar at all) to 7 [very familiar (status before the experiment)]. The trial procedure again remained the same in all experiments (see Figure 2).

A trial started with a fixation cross (150ms), followed by a 80ms blank screen. Then the stimulus was presented: in Experiment 1 either for 10ms, 50ms, 100ms, or 500ms (between subjects); in Experiment 2a 10ms or 50ms (within subjects), 2b 10ms or 100ms (within subjects), 2c 10ms or 500ms (within subjects) and Experiment 3 100ms or 1000ms. Subsequently, a 80ms blank screen was presented followed by a 200ms random noise mask which covered the entire screen. Then the response scale(s) appeared on the screen: in Experiment 1, participants were instructed to respond as fast as possible to the question "Picture ambiguous? Yes or No?" by pressing indicated buttons on a Cedrus Button Box device. The same trial procedure as in Augustin et al. [76] was performed, since similar materials (reproductions of artworks) were used in the study. In the second series of experiments (2a to 2c, 3), the keyboard was used to measure responses from 1 to 7 to the scales liking (How much do you like the current

picture? 1: not at all, 7: very much), interest (How interesting is the current picture? 1: not interesting at all, 7: very interesting), and subjective fluency (How easy was it to perceive the current picture? 1: very hard, 7: very easy). The scales were presented in random order. Findings of ERP studies suggest that higher-level visual processing like identification or classification is accomplished after approximately 150ms [80,90–92]. Therefore, the time of post stimulus blank (80ms) and the presented mask (200ms) were chosen to guarantee the processing of these higher-level visual features and similar to the procedure presented in Augustin et al. [76].

Stimuli

In the present study, 36 pairs of pictures were used plus a set of 32 distractor images. Each pair consisted of an original Magritte painting (ambiguous) and a manipulated (non-ambiguous) version of it. For the manipulated versions, using Adobe Photoshop CS3, we "corrected" the ambiguity to render the painting non-ambiguous in order to provide a fair control condition. This ensured that the original and the manipulated version only differed in terms of ambiguity. For example, objects which were placed in an uncommon way (e.g. the engagement ring around the grand piano in the painting "La main heureuse, 1953") were either removed (in this example the ring) or modified. Or in "Le Modele rouge, 1947", where parts of the foot and the toes are combined with brown shoes,

the toes were replaced by a “full version” of the shoes. It is important to note, that the picture pairs were balanced across participants: a person saw either the original, ambiguous picture or the manipulated, non-ambiguous one.

In a pre-study, 50 pairs of these artworks were rated according to complexity, mood content, and ambiguity on 7-point scales by 22 participants (Mean age: 24.85 years; 14 female, 8 male). *Ambiguity* was balanced over two experimental versions so that the participants only saw either the original or the corresponding manipulated version of a painting. For the main experiments, we chose picture pairs which significantly varied in their ambiguity, i.e. significantly higher ambiguity ratings for the original picture than for the manipulated version. Further, the picture pairs had to meet the criteria a) medium mood content (mean within the range of 3.0 and 4.0) and b) similar subjective complexity (mean within the range of 3.0 and 4.0). Moreover, 32 distractor images (16 surrealist = ambiguous; 16 realistic = non-ambiguous) were presented in order to increase the variety of styles that participants were not able to make assumptions concerning the main hypotheses. Responses to distractors were excluded from later analyses. The images measured 269 × 390 pixels (portrait format) or 390 × 269 pixels (landscape format) with a resolution rate of 100 dpi. For a detailed stimulus and distractor list, please see Table S1 (supporting information). Example stimuli and data will be available on request – please contact the corresponding author.

Part A: Experiment 1a Classification

When are people able to successfully classify ambiguous content of pictures? In this respect, four presentation durations (10ms, 50ms, 100ms, and 500ms) were varied. Signal detection analyses [93] were used to analyze the sensitivity (d') of classification performance.

Participants. Sixty-four psychology students between the ages of 18 and 36 ($M = 21.90$, $SD = 3.30$; 11 male, 53 female) with normal or corrected to normal vision and color vision participated for course credit. None of them had a specific background in art. Written consent was obtained from each participant prior to the experimental session.

Design. A 2 (*Ambiguity*: ambiguous versus non-ambiguous) × 4 (*Duration*: 10ms, 50ms, 100ms, 500ms) mixed design was used in the present experiment. The variable *ambiguity* was balanced within subjects. The participants were randomly assigned to one of the four *duration* conditions. As dependent variable, the classification performance in terms of d' was measured.

Results and Discussion Experiment 1a Classification

D primes (d') for each participant were computed, based on hits, false alarms, misses and correct rejections categorization [93]. Extreme values were corrected by using $0.5 \div n$ for rates of 0 and $(n - 0.5) \div n$ in the case of rates of 1 as proposed by Macmillan and Kaplan [94] or Stanislaw and Todorov [95]. The d' of 10ms, 50ms, 100ms, 500ms were submitted to one sample t tests for each duration condition and to a one-way analysis of variance (ANOVA) with duration (10, 50, 100, 500 ms) as between subjects factor. The one sample t tests were

performed to check the difference of the mean d' per *duration* condition to chance level ($d' = 0$). Results showed that the mean d' deviated significantly from zero at the specified .05 level (95% CI) in all *duration* conditions: 10ms $t(15) = 2.13$, $p = .049$; Cohen's $d = 1.11$, CI of the mean [0.01, 0.78]; 50ms $t(15) = 5.64$, $p < .001$, Cohen's $d = 2.92$, CI [0.55, 1.20]; 100ms $t(15) = 8.28$, $p < .001$, Cohen's $d = 4.27$, CI [0.82, 1.40]; and 500ms $t(15) = 9.11$, $p < .001$, Cohen's $d = 4.70$, CI [1.05, 1.69]. In addition, the CIs for each participant-based d' [96] were calculated. If the individual CI of each participant's d' includes 0, then the detection performance is not significantly better than chance. The results show that the number of participants with a lower CI bound above 0 increased with longer *duration* conditions: 10ms 1 of 16; 50 ms 5 of 16; 100 ms 8 of 16; and 500 ms 12 of 16, signaling that the longer the stimuli were presented the better the detection performance of the participants became. The mean hit rate ($M = .61$) and mean correct rejection rate ($M = .68$; sampled over all conditions) indicate further that ambiguous images were detected as good as non-ambiguous images were rejected.

Performance differences between the duration conditions were analyzed using an ANOVA with *duration* (10, 50, 100, and 500 ms) as fixed factor and the d' as dependent variable. Participants' classification performance at 10 ms presentation duration was less sensitive ($M = 0.39$) than at 100 ms ($M = 1.12$) and 500 ms ($M = 1.37$) duration resulting in a significant main effect, $F(3,60) = 7.14$, $p < .01$, $\eta^2 = .25$. No differences were found among 50, 100, and 500ms (see Figure 3). The familiarity of pictures (measured in a separate block after the main experiment) might influence the performance of classification. Therefore, the number of familiar pictures (pictures which received ratings from 4 to 6 on the 6-point scale) per participant were used as a covariate in an additional ANCOVA. Results showed no significant influence of familiarity on the d' , $F(1,63) = 0.09$, $p = .93$, $\eta^2 < .01$.

Experiment 1a provided information concerning the duration needed to classify the picture content successfully. Starting at 100ms presentation duration, half of the participants were able to detect the ambiguity above chance level (as indicated by the 95% CI of d'). In Experiment 1b differences in reaction times (RT) for ambiguous and non-ambiguous pictures were tested.

Part A: Experiment 1b Classification RT

In this experiment reaction times were measured in order to test possible effects of ambiguity in a classification task. According to previous results, ambiguous pictures could either be classified slower (fluency account) or faster (object-scene violations) than non-ambiguous pictures.

Participants. Twenty-four psychology students between 18 and 26 years ($M = 20.79$; $SD = 1.87$; 17 female) with normal or corrected to normal vision and color vision participated in the present study. None of them had been tested in Experiment 1a or had a specific background in art. Again, written consent was obtained prior to the experiment.

Stimuli. The same twenty-eight picture pairs were used as in Experiment 1a.

Design. Design, overall procedure and trial procedure remained the same as in Experiment 1a. In order to test

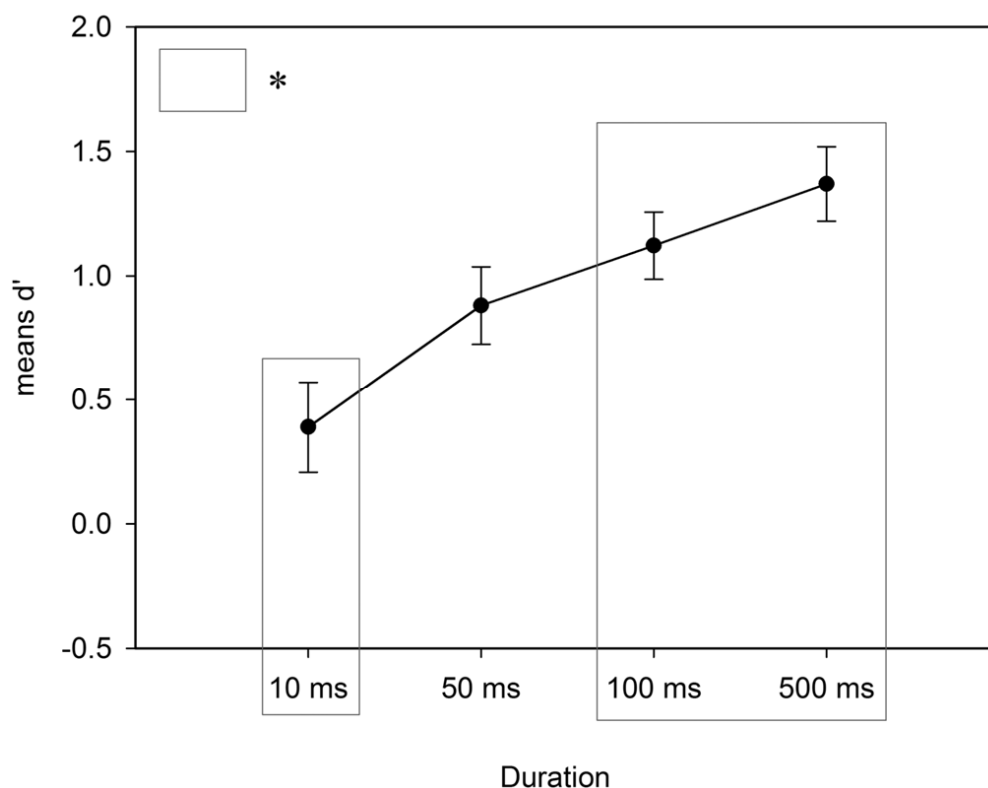


Figure 3. Mean d' in all duration conditions. The significant difference between the duration conditions 10ms and 100ms / 500ms (see gray boxes) is marked with an asterisk. Error bars represent ± 1 SE.

doi: 10.1371/journal.pone.0074084.g003

differences in the ability to classify the picture content. a reaction time based task was implemented: instead of a fixed presentation time, after the stimulus onset participants were asked to respond as fast as possible (Picture ambiguous? Yes / No). At a button press the stimulus presentation ended.

Results and Discussion Experiment 1b

Reaction times (RTs) of correct responses (hits and correct rejections) were analyzed. RT outliers (more than two standard deviations from the mean, 4% excluded) were excluded. The RT means for ambiguous ($M = 1546.09\text{ms}$; $SD = 670.66$) and non-ambiguous ($M = 1587.87\text{ms}$; $SD = 719.32$) trials were compared in a paired sample t test. Results showed no significant difference at the specified .05 level between the responses to ambiguous and non-ambiguous stimuli: $t(23) = 0.59$, $p = .55$, n.s., Cohen's $d = 0.05$, 95% CI on the difference between means [-105.80, 189.48].

Surprisingly, there were no differences between the two *ambiguity* conditions. Nevertheless, our findings are in accordance with recently published data by Vö and Henderson [53,97], who did not find reaction time differences for semantic or syntactic violation detection in scenes and consistent control stimuli [53,97]. The mean RTs are comparable with those found for semantically (1964ms) and syntactically (1936ms) consistent and semantically (2067ms) and syntactically (2094ms) inconsistent object-scene combinations [53]. The slightly longer RTs in Vö and Henderson's [53] results might be due to higher stimulus complexity. The authors concluded that RT differences for consistent and inconsistent object-scene stimuli might have been due to the saliency of inserted inconsistent objects or spare scene layouts. As we did not manipulate the "inconsistent" ambiguous pictures, the stimuli did not contain such image-based artifacts.

Different from previous fluency results, in Experiment 1b no speed advantage for non-ambiguous pictures was found.

Table 1. Results overview of the ANOVAs¹ with repeated measures of Experiment 2a, 2b, 2c and split by the dependent measures liking, interest, and felt fluency (For all three Experiments: df = 1; Error df = 19).

Experiment	2a			2b			2c		
	10/50ms			10/100ms			10/500ms		
Variable	F	p	ηp^2	F	p	ηp^2	F	p	ηp^2
<i>liking</i>									
ambiguity	0.44	.05	.01	0.03	.87	.00	5.22	.03*	.22
duration	14.29	.001*	.43	11.62	.003*	.38	2.90	.11	.12
ambiguity×duration	0.08	.76	.01	1.89	.19	.08	1.82	.18	.09
<i>interest</i>									
ambiguity	15.40	<.01*	.45	21.75	<.01*	.53	27.72	<.01*	.58
duration	10.84	.004*	.36	14.44	.001*	.43	12.60	.002*	.40
ambiguity×duration	4.51	.04*	.19	12.48	.002*	.40	9.14	.007*	.33
<i>felt fluency</i>									
ambiguity	8.42	.009*	.31	10.29	.005*	.35	3.97	.06	.16
duration	61.23	<.01*	.76	375.52	<.01*	.95	306.41	<.01*	.93
ambiguity×duration	0.75	.34	.04	0.61	.45	.02	0.01	.87	.01

Note: Significant *p*-values at the specified .05 level are marked with an asterisk.

However, Oppenheimer [4] noted that equating fluency to reaction times might not be sufficient for all types of fluency and that a subjective feeling of fluency depends on how people anticipate difficulty [8]. He concluded on page 238, that "measuring reaction time ignores this element of the fluency experience entirely" [4]. Therefore, we measured "felt fluency" in addition to aesthetic measures of liking and interest to check our conceptual fluency manipulation (ambiguity).

Part B: Experiment 2a, 2b and 2c Appreciation of ambiguity

The aim of the current series of experiments was to investigate the relationship between ambiguity/fluency and aesthetic judgments. In order to compare the two fluency manipulations, ambiguous (original) and (manipulated) non-ambiguous Magritte paintings were presented 10ms and 50ms (Experiment 2a), 10ms and 100ms (Experiment 2b) and 10ms and 500ms (Experiment 2c). Experiment 3 (100ms versus 1000ms) was run to compare longer durations. In all experiments, liking, interest and subjective fluency were measured as dependent variables.

Stimuli. For the present series of experiments, the set of stimuli used in Experiment 1a and 1b was extended to 36 pairs of pictures in order to provide a higher number of stimuli in the duration conditions (see section Design). Again, each pair consisted of an original Magritte painting (ambiguous) and a manipulated (non-ambiguous) version of it. All stimuli were presented in the same pixel dimensions (269 × 390 pixels) with a resolution rate of 100 dpi.

Participants. Sixty (twenty per experiment) participants with normal or corrected to normal vision took part for course credit. The participants' ages (45 female, 15 male) ranged between 18 and 33 years with a mean age of 22.23 years (SD = 2.67). The procedure was explained prior to the experiment, and written consent was obtained from each participant.

Design. A 2 (*ambiguity*) × 2 (*duration*) within subjects design was used. As in Experiment 1a and 1b, *ambiguity* (ambiguous versus non-ambiguous) was manipulated via picture content and balanced across participants. Different to 1a and 1b, *duration* was set as within-subjects factor in order to manipulate fluency as reported in previous studies [9]. Due to the limited number of Magritte paintings which could be manipulated, we had to split the duration conditions. Therefore, three experiments were conducted to compare a) 10ms and 50ms (Experiment 2a), b) 10ms and 100ms (Experiment 2b), and c) 10ms and 500ms (Experiment 2c).

Results Experiment 2a, 2b and 2c

For each experiment, the data of three dependent variables were submitted to three repeated measures ANOVAs with *ambiguity* (ambiguous versus non-ambiguous) and *duration* (2a: 10ms versus 50ms; 2b: 10ms versus 100ms; 2c: 10ms versus 500ms) as within-subject factors and the dependent measures liking, interest, and felt fluency. In order to compare the findings of the three experiments, the results will be reported in a combined section for each dependent measure.

Effects on liking

A significant main effect for *ambiguity* was found in Experiment 2c (10 vs. 500 ms), $F(1,19) = 5.22$, $p = .03$, $\eta p^2 = .22$; in the Experiment 2a and 2b the ambiguity main effect did not reach significance: 2a [10 vs. 50ms: $F(1,19) = 0.44$, $p = .50$, n.s.], 2b [10 vs. 100ms: $F(1,19) = 0.028$, $p = .87$, n.s.]. The second within-subjects factor *duration* influenced liking significantly in Experiment 2a [10 vs. 50ms: $F(1,19) = 14.29$, $p = .001$, $\eta p^2 = .43$] and 2b [10 vs. 100ms: $F(1,19) = 11.62$, $p = .003$, $\eta p^2 = .38$] but not in 2c [10 vs. 500ms: $F(1,19) = 2.90$, $p = .11$, n.s.]. No significant interactions (*ambiguity* × *duration*, see Table 1) were found. For an overview of results please see Table 1 and Figure 4.

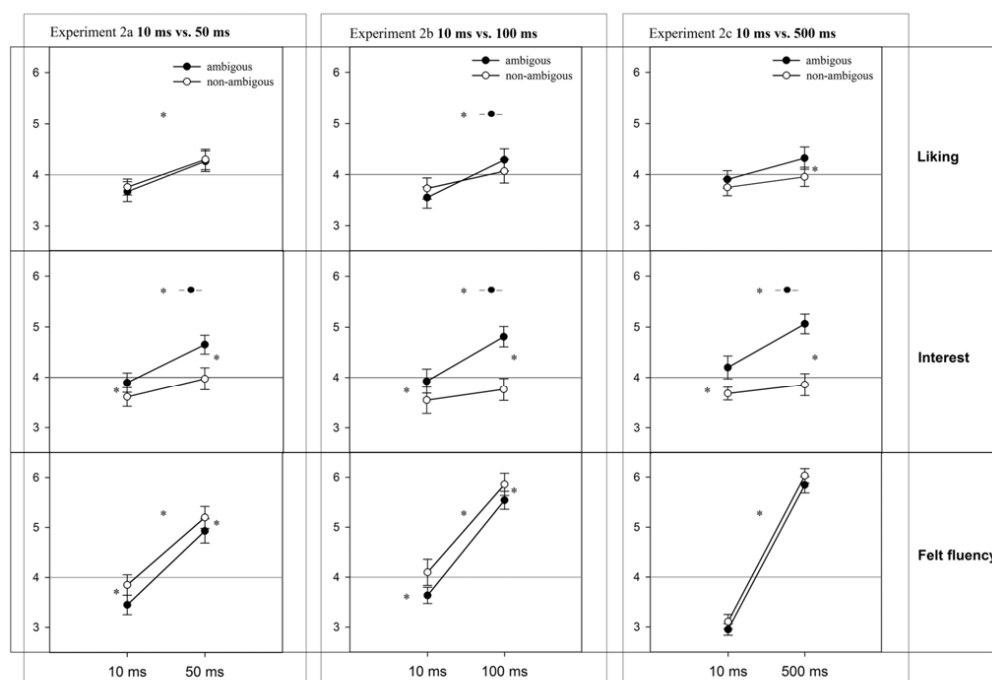


Figure 4. Overview of effects in Experiment 2a, 2b, and 2c.

doi: 10.1371/journal.pone.0074084.g004

In 2a and 2b, the perceptual fluency manipulation (*duration*) influenced participants' liking ratings. No effect for *duration* on liking was found in 2c. Post hoc tests (Bonferroni-adjusted simple main effects) revealed that in 2a ambiguous and non-ambiguous pictures received significantly higher liking ratings at 50ms. In 2b, the main effect of duration is based on significantly higher liking ratings for ambiguous pictures whereas ratings for non-ambiguous pictures did not increase significantly. In 2c, the conceptual fluency manipulation modulated participants' preferences: at 500ms presentation duration, participants rated the ambiguous pictures as more likeable than non-ambiguous pictures, whereas at shorter durations they did not.

Effects on interest

In all three experiments, for interest main effects of ambiguity and duration, as well as significant interactions between the two factors, were found (please see Table 1). The data pattern was consistent over all experiments: ambiguous pictures were found significantly more interesting than non-ambiguous pictures under short as well longer durations. Moreover, the mean ratings of interest for ambiguous pictures increased significantly from 10ms to 50ms, 10ms to 100ms, and 10ms to

500ms. This *duration* effect was not found for non-ambiguous pictures (see Figure 4).

Effects on felt fluency

In all three experiments, strong main effects for *duration* were found (see also Table 1). Participants rated the longer (50ms, 100ms, and 500ms) presented stimuli as more fluent than those presented for 10ms. *Duration*: 2a [10 vs. 50ms: $F(1,19) = 61.23, p < .01, \eta^2 = .76$]; 2b [10 vs. 100ms: $F(1,19) = 375.52, p < .01, \eta^2 = .95$]; and 2c [10 vs. 500ms: $F(1,19) = 306.41, p < .01, \eta^2 = .93$]. *Ambiguity*, representing a conceptual fluency manipulation, influenced the felt fluency ratings significantly in the expected way in Experiment 2a [10 vs. 50ms: $F(1,19) = 8.42, p = .009, \eta^2 = .31$] and 2b [10 vs. 100ms: $F(1,19) = 10.29, p = .005, \eta^2 = .35$]. Non-ambiguous pictures were significantly rated as being more fluent than ambiguous images under short as well longer presentation durations. This effect was not found in Experiment 2c [10 vs. 500ms: $F(1,19) = 3.97, p = .06, \eta^2 = .16$, trend].

Discussion Experiment 2a, 2b, and 2c

In accordance with assumptions regarding art, we found that ambiguous paintings can be appreciated. Effects in the favor of

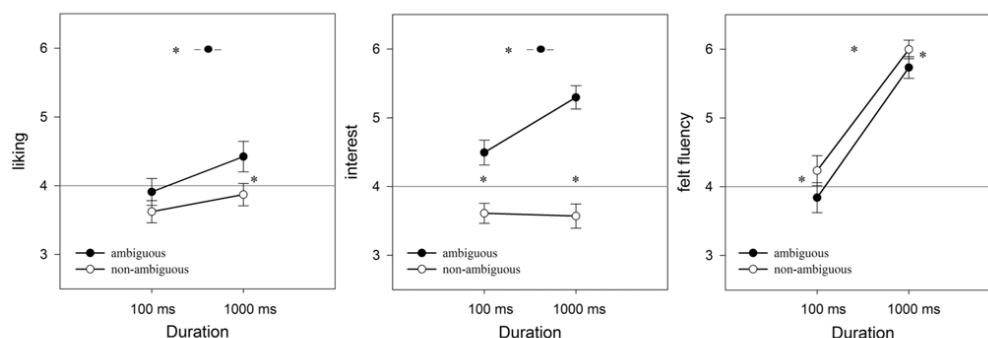


Figure 5. Results for liking (left), interest (in the middle), and felt fluency (right) for ambiguous (black) and non-ambiguous (white) pictures split by duration (100ms versus 1000ms).

doi: 10.1371/journal.pone.0074084.g005

ambiguity were found for liking judgments at 500ms and interest judgments from 50 to 500ms. The findings are in accordance with optimal challenges that can be experienced as self-rewarding leading to a positive experience and satisfaction [68]. Ramachandran and Hirstein [52] similarly stated on page 30 that "it is as though an object discovered after a struggle is more pleasing than one that is instantly obvious". This mechanism explains why our participants rated ambiguous pictures significantly more interesting than non-ambiguous ones – even though the felt fluency ratings indicate that those pictures were perceived harder.

Nevertheless, in Experiment 2c, no effect of *duration* on liking was found in combination with a not significant difference for *ambiguity* on felt fluency ratings. This was puzzling in the first instance, as at 500ms it could be that both ambiguity classes were perceived equally fluent. However, no effect was found in the 10ms condition, as well, which speaks against that suggestion. We therefore hypothesized that the perceived time difference was too obvious so that the participants identified duration the source of fluency. This identification might have led to a) an adjustment of liking ratings and b) the usage of just the temporal fluency manipulation to judge felt fluency. If the source of fluency is obvious, it has been suggested that judgments are "corrected" [4,66,98,99]. Oppenheimer [4] noted on page 238 that "however, when there is an obvious alternative cause for fluency people will spontaneously discount the fluency experience, and the effects of fluency on judgment will be diminished or reversed". In order to test this explanation, an additional Experiment with 100 and 1000 ms presentation duration was run ($N = 30$). The presentation durations were chosen a) to replicate one duration condition (100ms) and compare it with the already existing data and b) to check whether effects of liking get more pronounced under longer durations than 500ms.

Experiment 3

Participants. Thirty undergraduate students participated for course credit. The participants' ages (27 female, 3 male)

ranged between 20 and 38 years with a mean age of 23.53 years ($SD = 4.30$). All had normal or corrected to normal vision and written consent was obtained from each participant.

Stimuli and Design. Stimuli and Design are identical to Experiment 2a, 2b, and 2c. The presentation duration was varied on two levels (100ms versus 1000ms).

Results Experiment 3

Effects on liking. Corresponding to the previous findings, we found significant main effects for *ambiguity*, $F(1,29) = 10.28$, $p = .003$, $\eta^2 = .25$, and *duration*, $F(1,29) = 12.81$, $p = .001$, $\eta^2 = .31$. Both factors did not significantly interact, $F(1,29) = 1.14$, $p = .28$, n.s. Simple main effects showed that the factor *duration* positively influenced only the ratings of ambiguous pictures (see Figure 5). Further, at 1000ms, ambiguous pictures were liked more than the non-ambiguous counterparts.

Effects on interest. An identical (to 2a, 2b, and 2c) results pattern was found for interest. Both main effects and the interaction reached significance: *ambiguity*, $F(1,29) = 100.58$, $p < .001$, $\eta^2 = .78$, *duration*, $F(1,29) = 8.88$, $p = .006$, $\eta^2 = .24$, and *ambiguity* $\times$ *duration*, $F(1,29) = 15.16$, $p = .001$, $\eta^2 = .33$.

Effects on felt fluency. Of most importance, effects of *ambiguity* were significantly shown in this additional experiment, $F(1,29) = 25.96$, $p < .001$, $\eta^2 = .46$. In both *duration* conditions, non-ambiguous pictures were perceived as more fluent than ambiguous ones. Moreover, *duration* showed a significant increase from 100ms to 1000ms in both ambiguity conditions, $F(1,29) = 135.39$, $p < .001$, $\eta^2 = .81$, but no interaction between the two factors was found, $F(1,29) = 0.73$, $p = .400$, n.s.

We assume that the comparison of a relatively long duration (500ms) with a brief display (10ms) presumably caused the divergent conceptual fluency effects in Experiment 2c. Furthermore, we successfully replicated our findings in one duration condition (100ms) and showed that effects of liking get more pronounced under longer durations (1000ms).

General Discussion

The present study examined behavioral responses (classification, aesthetic judgments, felt fluency) to ambiguity (ambiguous versus non-ambiguous). In the first part, we focused on the accuracy of classification performance (ambiguous? Yes/no) at four different presentation durations (Exp. 1a: 10ms, 50ms, 100ms, 500ms) and on the speed of classification under a RT-based presentation duration. In the second part, the relationship between aesthetic appreciation and ambiguity/fluency was tested. The results of both parts will be discussed separately, leading to a final overall conclusion and outlook.

Part A: Classifying ambiguous and non-ambiguous content

We found that the performance was above chance level even at 10ms presentation duration. Not surprisingly, the classification performance increased over the fixed presentation durations with significant differences between 10ms and 100ms as well as 10ms and 500ms (mean d'). In all four duration conditions mean d' s significantly deviated from zero suggesting that the mean performance (mean d') was above chance level. These results are in line with previous findings showing that content of pictures can be processed under short (masked) presentation durations e.g. under 10ms [76] or 27ms [75]. Nevertheless, the CI of d' on a participant level showed that until 100ms half of the participants were not able to classify the stimuli reliably. Even though the cognitive effort to classify ambiguous picture is probably higher than classifying real-world scenes, it is surprising that even under 500ms presentation duration 4 of 16 participants performed below chance level. People differ in their speed of information processing due to differences in cognitive processing speed on a reflectivity-impulsivity continuum e.g. [100]. Therefore, such inter-personal differences might have influenced the participants' performance.

In Experiment 1b, no RT- differences were found between ambiguous and non-ambiguous stimuli. These findings are similar to those found in studies investigating object-scene inconsistencies [53]. Vö and Henderson [53] argued that in those studies replicating the findings of Loftus and Mackworth [54], artificial saliency effects (artificial shadows based on manipulation techniques) or low complexity might have caused the pop-out effects of inconsistent objects. In our pre-studies and the main studies, participants were asked if they experienced something odd. No one mentioned picture-related facts. Thus, these results might also support the artificial saliency theory. One major difference between previous studies and the present was the task. Often visual search tasks – searching for a specific continent or inconsistent target – were used rather than our more unspecific instructions to search for any ambiguity in the stimuli. Any artistic (or art-like) stimulus might evoke a prolonged search because in such materials ambiguities arise more often. In highly controlled real-world scenes the expectation for an occurrence of an inconsistent object (and the probability that inconsistencies are present) is low; the opposite might be the case for artworks.

Therefore, future studies should aim to compare our study with additional control stimuli (real world scenes) and/or use eye-tracking methods in combination with saliency toolbox to empirically check the differences or similarities to the object-scene inconsistencies discussed above. A second explanation for the found effects is related to the conceptual fluency manipulation. RT advantages were found for perceptually fluent stimuli [36]. However, Oppenheimer [4] noted that reaction time differences are not sufficient for all types of fluency and that a subjective feeling of fluency is not measured by those RT differences. Accordingly, the results for measured “felt fluency” in the present study (Part B, see below) indicate that at 10, 50, and 100ms presentation duration, the participants indeed perceived the ambiguous stimuli as more disfluent than non-ambiguous versions, in accordance with Oppenheimer's statement. In future studies we plan to use electrophysiological methods to objectively measure effects of fluency, in addition. Some studies e.g. [7,63] showed that a specific pattern of facial muscle activation is present when fluent stimuli are presented. The subtle changes in facial muscle activation might reveal a more specific insight than RTs and be also of interest for follow-up studies of Part B.

Part B: Appreciation of ambiguity

In Part B, a perceptual fluency manipulation (presentation duration; 10ms versus 50ms; 10ms versus 100ms; and 10ms versus 500ms) as well as a conceptual fluency manipulation (ambiguous versus non-ambiguous stimuli) were used to test whether ambiguity in the arts can be appreciated.

The *duration* hypothesis – aesthetic judgments for ambiguous and non-ambiguous judgments increase with processing fluency and thus the presentation duration – was partly confirmed by the data. In Experiment 2a (10 versus 50ms) the expected pattern for both ambiguity classes was found for liking. In Experiment 2b, post hoc tests showed only a significant increase for ambiguous but not for non-ambiguous pictures. In all experiments the very same pattern was observed for interest. In Experiment 2c (10 versus 500ms), no duration effect on liking was found but, in contrast to 2a and 2b, an effect of conceptual fluency. This supports the hypothesis that effects of ambiguity occur at longer presentation durations. Surprisingly, conceptual fluency significantly influenced the interest ratings in the favor of ambiguous pictures much earlier than liking, namely at 50, 100, and 500ms. Even though the ambiguous pictures were rated as more interesting than the non-ambiguous ones, they were subjectively more difficult to perceive at 50 and 100ms. At 500ms no significant difference was found. This finding might be due to a) the greater –and more obvious – time difference between the duration conditions (10ms versus 500ms) or b) could represent a successful, self-rewarding –personal, subjective – interpretation process. In order to test the former explanation that only the temporal fluency manipulation could have been used for the judgments of felt fluency, we ran an additional experiment (Experiment 3) which varied longer durations (100ms versus 1000ms). Our findings suggest that indeed the perceived differences in duration in Experiment 2c have caused the deviant findings. Moreover, we replicated our findings at 100ms and extend it to

the 1000ms condition. Effects of liking were more pronounced than at 500ms which suggests, that effects of ambiguity emerge over time. This is also in line with previous results that prolonged viewing time allows alternative interpretation(s) [14].

Theories of aesthetic appreciation and aesthetic judgment in the arts [3] assume that the influence of variables related to earlier processing stages can be overwritten by those on later processing stages. There is some evidence for this hypothesis: Martindale, Moore, and Borkum [101] showed that semantic factors overwrote effects of complexity. Moreover, effects of "mere exposure" [102] were often not found or were weak for artworks as compared to other classes of stimuli – for a review please see 98. "Mere exposure" ("retrieval ease") was identified as one possible fluency manipulation [34] and follows the idea, that familiar (and thus fluent) stimuli are preferred over unfamiliar ones. By combining temporal, perceptual, and conceptual fluency manipulations, we demonstrated the temporal dynamics of such complex judgments, as for example aesthetic appreciation. Under shorter presentation durations, information processing, as proposed by the model of aesthetic appreciation and aesthetic judgments, is disrupted. Consequently, those variables active on earlier processing stages like perceptual fluency mostly impact the judgmental outcome. In combination with the first part of our study, we assume that higher order semantic factors like ambiguity start overwriting effects of fluency from approximately 500 ms onwards.

We already mentioned in the short discussion section of Experiment 2a to 2c that more challenging materials might be preferred and found more interesting due to self-rewarding mechanisms [52,68]. Several studies indicate that accomplishing the challenge of perceiving an artwork goes along with activation of the rewarding centers in the brain [103–105]. Especially the very robust findings for interest show that we tap into such processes. Interest is a precondition for learning, exploration and curiosity as it draws attention to novel things and experiences [83,86]. The nice thing in the arts might be that (ambiguous) paintings or poems must not be necessarily be new (be seen or read the first time) to enhance interest. The possibility to find new interpretations each time one sees a painting [3] again might prolong the appraisal of interest as compared to real world scenes. In contrast to pleasantness which motivates to stick with known, familiar events, the mechanism to be attracted by novel things can also have negative consequences like danger [83,86]. The "save" context of art perception but also the described characteristics of art – that there is not one solution – might be the reason why we are attracted by ambiguity in the arts.

Conclusions

The present study empirically provides some new insights to the role of ambiguity in the arts. Even though the present set of

stimuli was homogenous and therefore conclusions are limited, we showed what art-historical approaches have assumed for a long time, namely, that ambiguity is an enjoyable feature in the arts. In the past different types of ambiguity have been investigated in psychology; ambiguity and its role in aesthetic appreciation was only rarely addressed. Though artworks are a specific class of stimuli, nevertheless, stimuli like Magritte paintings definitely have features in common with e.g. linguistic stimuli, and show what visual and cognitive, lower and higher processes determine what we perceive and what we like. Ramachandran and Hirstein [52], for example, noted that surrealist art would be closely linked to metaphorical ambiguity in language as it plays with links between semantics and vision. In the present studies, employing Magritte paintings and testing competing hypotheses, we provide empirical data beyond previous attempts to relate the engagement to (sensory) ambiguous, multi-stable images to aesthetics [106]. The advantage of the present materials was the high comparability between the two ambiguity conditions. Responses to the here used distractor images showed similar results. In future studies a broader range of controlled materials should be used to show that in contrast to ambiguity arising in social situations, ambiguity in the arts can indeed be a source of pleasure. The reason might be the save context which ensures a playful and enigmatic aspect of aesthetic experience [52]. This playful aspect of aesthetic experience can be evolutionary essential as it comprises a fictitious playground to "train" problem solving and resolving ambiguity in real-world scenarios [70].

Supporting Information

Table S1. List of Magritte artworks used in the present experiments (Original title, year; in alphabetic order). (DOCX)

Acknowledgements

We thank Rolf Reber and an anonymous reviewer for their valuable comments and J. Neubauer, A. Medic, and M. Andrejevic who organized the participant recruitment and the testing.

Author Contributions

Conceived and designed the experiments: MJ HL MF. Performed the experiments: MJ. Analyzed the data: MJ. Contributed reagents/materials/analysis tools: MJ HL. Wrote the manuscript: MJ HL MF.

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Summary & Outlook

Art theories suggest that ambiguity in an artwork might be an essential feature for liking (Gamboni, 2002). Theories of processing fluency, on the other hand, suggest that ambiguity of a stimulus, rather results in displeasure (e.g., Reber, Schwarz, et al., 2004). Thus, in a series of experiments we studied the role of ambiguity in the arts.

We first measured the time course of ambiguity detection. In Experiment 1a, comparing ambiguous and non-ambiguous artworks, we found that, already at very short presentation durations of 10ms, performance in detecting ambiguity was above chance level (as indicated by d' scores significantly differing from 0). As presentation durations increased, performance further increased. Thus, ambiguity can be readily detected. This fast detection of ambiguity might probably due to evolutionary mechanisms. It seems plausible that detecting ambiguity in the environment is key for detecting danger and thus for survival (Blanchard et al., 2011).

In Experiment 1b, however, we found that ambiguity, compared to non-ambiguity was not detected faster in artworks. In other words, participants were not faster in detecting *an* inconsistency in the artwork compared to detecting *no* inconsistency. Here, two processes might cancel each other out. On the one hand, ambiguity should be detected faster because it violates the scene (so-called semantic pop-out, see Becker et al., 2007; Underwood et al., 2008). On the other hand, ambiguity should be harder to process and should thus lead to longer reaction times (Oppenheimer, 2008; Reber, Wurtz, et al., 2004). Disentangling these two approaches could be a topic for future research.

In Experiments 2a, b, c and 3 we measured whether there are differences in liking of ambiguity vs. non-ambiguity and whether these differences vary over time. In line with previous accounts of processing fluency (Reber, Schwarz, et al., 2004; Reber et al., 1998),

longer presentation duration resulted in higher liking in Experiments 2a, b, and 3. In Experiment 2c the duration effect did not reach significance. Regarding ambiguity, we found that at short presentation durations ambiguous and non-ambiguous artworks did not differ, whereas, starting at 500ms, ambiguous artworks were liked more than non-ambiguous. This effect of preference for ambiguity did not appear to be due to higher felt fluency of ambiguous artworks. They were always rated as less fluent than non-ambiguous.

Interest evaluations showed even more pronounced effects from presentation duration and ambiguity. While ambiguous artworks were found more interesting with longer presentation duration, non-ambiguous artworks did not show this increase. Additionally, at all presentation durations ambiguous artworks were found more interesting than non-ambiguous artworks.

By using more complex material compared to the previous contributions, we could show that the initial preference for easy-to process, non-ambiguous material breaks down when there is more time to process a stimulus. Possibly, higher-order processes of meaning making and insight overwrite effects of processing fluency (Leder et al., 2004). Furthermore, the findings are also in line with the recent model by Graf and Landwehr (2015). High ease-of-processing at early stages of processing leads to higher liking. Lower ease-of-processing at early stages of processing leads to further inspection of the stimuli and, in our case, to higher interest in the ambiguous artworks. Thus, at longer presentation durations, the challenge of resolving ambiguity might be more pleasurable than easy processing of a stimulus.

6) It felt fluent but I did not like it – Fluency effects in faces vs. patterns

Introduction

Previous studies on processing fluency have used rather simplistic stimulus material to test effects of higher ease-of-processing on liking. Line drawings of common objects (Forster et al., 2013; Reber et al., 1998; Winkielman & Cacioppo, 2001), dot patterns (Reber et al., 1998; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006), or word triads (Topolinski & Strack, 2009a) are among the typical materials used in previous research. However, in order to understand our processing of the everyday environment, the evaluation of objects such as artworks or faces is probably more relevant.

Faces in general are a special category in visual perception. Especially facial attractiveness has a strong influence. Unlike many other objects, attractive faces are perceived in a glance (Locher, Unger, Sociedade, & Wahl, 1993; Olson & Marshuetz, 2005), they bind attention (Leder, Tinio, Fuchs, & Bohrn, 2010), and can influence how a person is evaluated (Dion, Berscheid, & Walster, 1972; Eagly, Ashmore, Makhijani, & Longo, 1991).

According to processing fluency accounts, higher ease-of-processing should lead to higher liking of faces. Thus, the longer one looks at a face the more it should be liked. However, previous research has not supported this hypothesis. Interestingly, no effect of higher ease-of-processing (Gerger et al., 2011) or even reversed results—higher ease led to lower liking (Rashidi, Pazhoohi, & Hosseinchari, 2012)—have been found. As these previous experiments compared very short to relatively long presentation durations (Gerger et al., 2011: 40 vs 400 ms, Rashidi et al., 2012: 200 vs. 5000ms), the differences in ease-of-processing might have become too apparent to viewers and thus feelings of fluency were discounted as a source for liking evaluations (Bornstein & D'Agostino, 1994; but see Newell & Shanks, 2007).

Thus, we applied a more subtle ease-of-processing manipulation (variations in presentation duration between 100, 200, 300, and 400 ms), which in previous research showed robust effects of fluency (e.g., Reber et al., 1998). We measured the effects of this manipulation on ratings of high, medium, and low attractive faces via three variables: felt fluency, liking, and certainty. To test the possibility that a decrease in liking at longer presentation durations for faces (Gerger et al., 2011; Rashidi et al., 2012) is due to lower feelings of fluency, we assessed felt fluency in one block. In a second block, we measured liking as the main dependent variable. In this block we further measured how certain the participants were in their liking ratings. Previous research has shown that also certainty evaluations are sensitive to manipulations of ease-of-processing (Alter et al., 2007; Simmons & Nelson, 2006).

Faces of different levels of attractiveness were used to explicitly test the assumption that fluency is positively marked (Winkielman et al., 2003), an unspecific activation (Bornstein & D'Agostino, 1994; Mandler et al., 1987), or an amplifier of emotional valence (Albrecht & Carbon, 2014, for a thorough discussion, see pp. 17-23). If fluency is inherently positive, then liking ratings of faces should increase with higher ease-of-processing, regardless of attractiveness. If, however, fluency is an unspecific activation or an amplifier of valence, ratings of attractive faces might increase, whereas ratings of unattractive faces might decrease. For medium attractive faces, ratings might not change with higher ease-of-processing.

To exclude the possibility that our design was not suitable for eliciting fluency effects, we also presented abstract patterns as stimuli (Gartus & Leder, 2013) to a separate group of participants. As in faces, we varied pre-defined attractiveness in abstract patterns by presenting symmetric (high attractive), broken symmetric (medium attractive), and asymmetric (low attractive) exemplars (Gartus & Leder, 2013). Therefore, we tested whether

previous findings of a reversed fluency effect on faces (Gerger et al., 2011; Rashidi et al., 2012) are due to the specific design or whether faces in general represent a special category where fluency exerts different effects. Thus, we more rigorously addressed how feelings of fluency affect liking of different classes of objects.

Original Manuscript

RUNNING HEAD: FLUENCY AND FACES

It felt fluent but I did not like it – Fluency effects in faces vs. patterns

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Abstract

Whether you like a person or not is often appraised in a glance. However, under such short presentation durations stimuli are harder to perceive and according to fluency theory, thus, liked less. Given that liking considerably influences person perception, we tested how shorter compared to longer presentation durations affect liking in faces and in abstract patterns. To capture facets of fluency of processing we assessed felt fluency, liking, and certainty ratings. Following predictions of fluency theory, longer presentation durations led to higher felt fluency, certainty and positively affected liking judgments in the abstract patterns. In faces felt fluency and certainty also increased with longer durations. However, faces were liked less and liking was not related to felt fluency. In other words, in contrast to present fluency theory, faces may be more attractive when only seen for a short amount of time. Thus, fluency does not inevitably lead to more positive evaluations – it rather depends on the stimulus category used. We discuss these findings in terms of the special status faces have with regard to human perception and evaluation.

It felt fluent but I did not like it – Fluency effects in faces vs. patterns

Liking or disliking a face considerably influences person perception. Persons whose faces are liked more are considered to have more favorable personalities and higher moral standards (Dion, Walster, & Berscheid, 1972). This has important consequences in every-day life. For example, persons with more attractive faces report to have more dates, are more successful in mating, have better chances in getting hired, receive higher wages, and receive more favorable legal judgments (Little, Jones, & DeBruine, 2011; Pflueger, Oberzaucher, Katina, Holzleitner, & Grammer, 2012). Importantly, these effects can even arise at first sight. A glimpse of a face for about 100ms and shorter is already sufficient to draw social inferences and provide liking judgments in accordance with pre-classifications (Gerger, Leder, Tinio, & Schacht, 2011; Locher, Unger, Sociedade & Welsh, 1993; Olivola & Todorov, 2010; Olson & Marshuetz, 2005). This is surprising due to the fact that some theories suggest that at such short presentation durations stimuli are harder to perceive and thus liked less (Forster, Leder, & Ansorge, 2013; Reber, Schwarz, & Winkielman, 2004).

According to fluency theory people tend to prefer easier over harder to process information (Alter & Oppenheimer, 2009; Reber et al., 2004) particularly if this ease of processing is subjectively experienced (Constable, Bayliss, Tipper, & Kritikos, 2013; Forster et al., 2013). Previous studies, however, have reported contradictory results to fluency theory in faces (Gerger et al., 2011; Rashidi, Pazhoohi, & Hosseinchari, 2012), where faces were liked more under less fluent, short presentation durations. Given that fluency theory suggests that higher ease inevitably leads to higher liking, other underlying mechanisms might be at work. We thus tested how fluency manipulated by unobtrusive changes in presentation duration affected liking evaluations of faces. As a control category we used abstract patterns for which fluency effects have been reliably shown (Gerger et al., 2011; Halberstadt, 2006). Critically, we also employed subjectively felt fluency ratings. Given that faces compared to

non-face stimuli are processed very fast, efficiently, and automatically in dedicated or at least highly trained neuronal networks (Bindemann, Burton, Hooge, Jenkins, & De Haan, 2005; Bukach, Gauthier, & Tarr, 2006; Finkbeiner & Palermo, 2009; Kanwisher, 2000), this allows us to test whether manipulations in presentation durations affected perceived fluency and consequently liking in the same way.

In general, fluency theory provides a parsimonious account of why stimuli are appreciated by linking liking to the processing dynamics of a stimulus. The central tenet of fluency theory holds that the more easily or fluently a stimulus can be processed, the more easily information can be extracted from a stimulus, the more positive affect is triggered, and hence the more a stimulus is liked. Fluency is thought to be positively marked, as it suggests error-free processing, availability of appropriate knowledge structures, successful stimulus recognition, or, more generally, may indicate a positive state of affairs (Reber et al., 2004).

However, alternate accounts suggest that fluent processing rather provides a neutral unspecific activation signal which is then attributed to the stimulus or task (Bornstein & D'Agostino, 1994). Accordingly, higher fluency of processing increases neutral judgment dimensions of loudness, stimulus brightness or darkness (Mandler, Nakamura, Shebo, & Zand, 1987). Still other studies failed to replicate these findings (Seamon, McKenna, & Binder, 1998). With regard to emotional stimuli, fluency seems to increase emotional salience. Under fluent conditions emotionally positive stimuli are liked more, but negative stimuli are liked less (Albrecht & Carbon, 2014). Using faces and patterns that differ widely in their attractiveness level from high to medium to low allows us to pit these alternate explanations of fluency as being affectively positive or neutral against each other. If fluent processing is intrinsically positive then we would expect to find general increases in liking regardless of attractiveness level. Alternatively, we might find an enhancement depending on

attractiveness level—less attractive stimuli should be liked less and highly attractive stimuli liked more.

Fluency can be influenced by a wide range of factors including contrast, prototypicality, symmetry, familiarity, and presentation duration. Despite these very different sources, manipulations in these variables yield very similar results (Alter & Oppenheimer, 2009; Reber et al., 2004). We manipulated fluency through presentation durations which facilitates information extraction (Fei-Fei, Iyer, Koch, & Perona, 2007; Mackworth, 1963), supporting stimulus recognition and classification. In non-face stimuli, positive affect and liking have been shown to increase with longer presentation durations (Gerger et al., 2011; Reber, Winkielman, & Schwarz, 1998; Winkielman & Cacioppo, 2001) but not in faces (Gerger et al., 2011; Rashidi et al., 2012). Specifically, in Gerger et al. (2011), patterns and faces were shown for either 47 ms or 400 ms while affective changes were inferred via facial electromyographic measures of the *M. zygomaticus major*, used for smiling, indicating positive affect, and *M. corrugator supercili*, involved in frowning, indicating negative affect (Lang, Greenwald, Bradley, & Hamm, 1993). Only in patterns (see Winkielman, & Cacioppo, 2001 for similar results), but not in faces, did longer presentation duration lead to a higher activation of the *M. zygomaticus major*. In a further study by Rashidi et al., (2012), facial stimuli were presented for very short (200 ms) or very long presentation durations (5000 ms). Faces under longer presentation duration were liked less. These—in terms of fluency theory—divergent results could be due to specifics of the experimental designs, or also due to the specific category used—namely faces.

Regarding the experimental design in Rashidi et al., (2012) as well as in Gerger et al., (2011), faces were presented under largely differing time durations. Short and long presentation durations in Gerger et al. varied by a factor of 10 and even more in Rashidi et al.. This could have invited discounting effects (Bornstein & D'Agostino, 1994). Discounting

means that participants do not consider fluency for their liking ratings if they become aware of the source—much like participants not using their affect for judgment if they know where the affect stems from (Schwarz & Clore, 1983). It should be noted that some authors are quite critical about discounting as a factor (Newell & Shanks, 2007). Nonetheless, in order to prevent discounting we used more subtle variations in presentation durations (100ms, 200ms, 300ms, 400ms) as has been successfully done previously (Forster et al., 2013; Winkielman & Cacioppo, 2001). We posited that if the effect of faces being rated higher in liking under shorter presentation durations persisted with these more subtle variations then discounting could be ruled out as a possible explanation.

That said, discounting cannot explain the contradictory results in full, due to the fact that in Gerger et al. (2011) a fluency effect was found in patterns and but not in faces. This could be due to the specific status faces have in human perception and evaluation. Compared to non-face stimuli saccades towards faces are very fast and can be performed within 100 to 110ms (Crouzet, Kirchner, & Thorpe, 2010). Non-consciously perceived faces engage cognitive processes regardless of attention directed towards them, whereas for non-face stimuli, attention has to be oriented towards the stimulus (Finkbeiner & Palermo, 2009) indicating a fast capture and binding of attention in faces (Bindemann et al., 2005). Even small amounts of visual face information—but not non-face stimuli (houses)—presented for a very short time (< 100ms), suffices to provide coarse attractiveness categorizations (Olson & Marshuetz, 2005). In sum these results suggest especially fast and efficient processing of faces in our cognitive system. Thus, manipulations in presentation durations between 100 to 400ms might hardly effect the subjective experience of fluency. Recently, Forster et al., (2013) showed that subjective experience of fluency is a critical factor in explaining the link between higher fluency and higher liking. Fluency effects are more pronounced if accompanied by corresponding changes in subjectively experienced fluency—that is when participants have the impression that a stimulus was easy to process. Measuring subjective

fluency thus allows us to directly test whether fluency increases with increasing presentation durations and whether this affected liking judgments in faces as well as patterns.

Alternatively, due to the number of variables that affect facial attractiveness, subjectively felt fluency might only play a minor role in assessing liking in faces. Faces are a highly meaningful category where liking depends on multiple sources ranging from perceptual to experiential, sexual, and social factors (Cunningham, Barbee, & Philhower, 2002). For example, besides perceptual factors such as averageness and symmetry (Gerger & Leder, 2014; Little et al., 2011), facial attractiveness is influenced by perceived familiarity (Tinio, Gerger, & Leder, 2013), assessed mate quality (Thornhill & Gangestad, 1999), and social information (Golle, Mast, & Lobmaier, 2013; Martens, Tracy, & Shariff, 2012). Under such a variety of sources fluency might constitute only but one source. Patterns, in contrast, are rather meaningless, and liking will be mainly determined by the systematically varied perceptual factors of complexity and symmetry (Gartus & Leder, 2013; Jacobsen & Hofel, 2002). Thus, perceived fluency might play a much stronger role. If this is the case we would expect to find positive correlations of subjective fluency and liking in patterns but significantly smaller correlations in faces.

Besides subjective fluency and liking we also included ratings of how certain participants were about their liking decision. This was based on the consideration that higher ease of processing signals “progress toward successful recognition of the stimulus, error-free processing, or the availability of appropriate knowledge structures to interpret the stimulus” (Reber et al., 2004, p. 366; see also Winkielman, Schwarz, Fazendeiro, & Reber, 2003). If fluency indicates successful recognition or error-free processing, then participants should be more confident about their perception, resulting in higher certainty judgments at longer presentation durations (Alter, Oppenheimer, Epley, & Eyre, 2007; Simmons & Nelson, 2006),

which facilitate information extraction and categorization processes (Fei-Fei et al., 2007; Macworth, 1963).

To sum up, we tested how unobtrusive increases in presentation duration (100ms, 200ms, 300ms, or 400ms) affected liking ratings of faces and abstract patterns. According to fluency theory longer presentation durations should increase liking for both types of stimuli. These changes should be accompanied by corresponding changes in subjectively experienced fluency. Participants should also be more certain about their liking decision under longer presentation durations. However, as faces are a special category with regard to perception and evaluation, such fluency effects might not be found in faces.

Method

Participants

In the study, 64 volunteers (34 men) took part. Age range of the participants was 19 to 45, with a mean age of 26.16 years ($SD = 5.51$). Half of the participants rated faces (32 participants, 18 men), the other half rated patterns (32 participants, 16 men). Prior to the experiment color vision and visual accuracy was assessed using standardized tests.

Stimuli

Faces

We selected 112 (half male) face images (size: 630 x 819 pixels) out of the stimulus set of Schacht, Wehrheid, and Sommer (2008). This set consists of professionally photographed faces that vary in attractiveness from high to medium to low. The faces are standardized in view (frontal), gaze direction (frontal), lighting, facial expression (neutral), and background (grey). In the experiment, faces were presented at four different presentation durations (100, 200, 300, 400 ms). To prevent stimulus repetition, which could result in mere

exposure effects (Zajonc, 1968), every face was only shown once—either for 100ms, 200ms, 300ms, or 400ms. Thus, we divided the faces in four equally sized groups with the restrictions that these groups should not differ in liking and that approximately 1/3 of the stimuli belonged to the low, medium, or high attractiveness range. Liking ratings were provided in a pre-study on seven point Likert scales (Schacht et al., 2008). The four groups did not differ in liking, $F(3, 104) = 0.011$, $p = \text{n.s.}$. Group to presentation duration assignment was balanced over participants.

Abstract patterns

The abstract patterns stem from the stimulus set of Gartus and Leder (2013). This stimulus set was designed to study the combined effects of symmetry and complexity on liking. The effects of symmetry and complexity are rather stable across different participants with symmetry being the strongest predictor for liking ratings followed by complexity (Gartus & Leder, 2013; Jacobsen & Höfel, 2001). Complexity was defined by the number of triangle elements constituting a pattern. Additionally, the patterns differed in symmetry. Symmetrical patterns showed mirrored symmetry along the vertical, horizontal, or transversal axes, and non-symmetrical showed no common symmetry axis. Additionally, we included a third category - broken symmetrical stimuli - for which only one triangle element was shifted away from full symmetry. In total, 144 stimuli were selected which were divided into four groups - each consisting of 12 symmetrical, 12 broken-symmetrical, and 12 non-symmetrical stimuli which corresponded to high (symmetrical), medium (broken-symmetrical) and lowly (non-symmetrical) liked stimuli. These groups were formed with the additional restriction that they should neither differ in liking, $F(3, 140) = 0.01$, $p = \text{n.s.}$, nor in complexity, $F(3, 140) = 0.22$, $p = \text{n.s.}$. Group to presentation duration assignment was systematically balanced across participants. The abstract patterns were presented at a size of 600 x 600 pixels.

Design and Procedure

All testing took place at the Faculty of Psychology, University of Vienna. At arrival, participants were informed about experimental procedures and signed a consent form. Half of our participants received faces as stimuli and the other half abstract patterns. The experiment was run on personal computers using E-Prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002). All instructions and stimuli were presented on a 19'' LCD monitor with a resolution of 1280 x 1024 at a refresh rate of 60 Hz.

The experiment consisted of two blocks – a liking block and a subjective fluency block. In one block participants provided liking ratings (How much do you like this stimulus?) which were subsequently followed by certainty ratings (How certain are you about your decision?). Both ratings were performed on 7-point Likert scales ranging from 1 *not at all* to 7 *very much*. In the other block participants provided subjectively felt fluency ratings (How easy was this stimulus to perceive?) on a 7-point Likert scale ranging from 1 *very easy* to 7 *very hard*. Liking and fluency ratings were given in separate blocks to prevent possible discounting effects (Bornstein & D'Agostino, 1994).

Block order—felt fluency or liking block first—was counterbalanced across participants. Each trial started with a fixation cross for 2000ms followed by the stimulus. The stimulus was shown for either 100, 200, 300, or 400ms followed by a 500ms white noise mask (Forster et al., 2013). After the mask participants gave their responses. After finishing the last trial the participants filled out a post-questionnaire regarding the assumed purpose of the experiment. Finally, participants were debriefed and thanked. In total, the experiment took about 30 minutes.

Results

Figures 1, 2, and 3 show means and standard errors for the felt fluency, liking, and certainty ratings, respectively. Ratings for felt fluency were inverted to simplify interpretation. Higher

ratings represent higher felt fluency, higher liking, or higher certainty. To analyze whether manipulations in presentation durations led to the expected fluency effects, we calculated three separate mixed-factors analyses of variance (ANOVA) with the between-subject factor *stimulus class* (faces, patterns), and the within-subject factors *presentation duration* (100, 200, 300, 400ms) and *stimulus attractiveness* (high, medium, low) for felt fluency, liking, and certainty. In case of significant main effects or interactions, follow up analyses are reported (planned contrasts for the effects of presentation duration within stimulus groups). Greenhouse-Geisser corrections were applied when assumptions of sphericity were violated. This can be seen in the adjusted degrees of freedom. Additionally, we calculated correlations among the felt fluency and liking ratings on a subject-wise basis, separately for faces and patterns and tested whether these correlations significantly differed from each other. All significance tests for correlations are computed with Fishers-z-transformed correlation coefficients. The reported correlations coefficients are retransformed Pearson correlation coefficients. We first report the felt fluency ratings, then the liking and certainty ratings, followed by the correlational analyses.

Felt fluency

We assumed that felt fluency increases with presentation duration, which was confirmed by a significant main effect of presentation duration, $F(1.35, 84.20) = 51.61, p < .001, \eta_p^2 = .45$, see Figure 1. Stimulus class had no influence on this effect of presentation duration, $F(1.36, 84.20) = 1.38, p = .25, \eta_p^2 = .02$, for the presentation duration $\times$ stimulus class interaction, and $F(4.87, 302.40) = 0.82, p = .82, \eta_p^2 < .01$, for the presentation duration $\times$ attractiveness $\times$ stimulus class interaction. In both, patterns, $F(3, 60) = 7.13, p < .001, \eta_p^2 = .26$, and faces, $F(3, 60) = 13.64, p < .001, \eta_p^2 = .41$ (planned contrasts), felt fluency ratings significantly increased when stimuli were presented for longer time periods.

A main effect of attractiveness, $F(1.35, 83.74) = 19.42, p < .001, \eta_p^2 = .24$, qualified by a significant attractiveness $\times$ stimulus class interaction, $F(1.35, 83.74) = 4.19, p = .045, \eta_p^2 = .06$, indicated that attractiveness influenced the felt fluency ratings differently in faces and patterns. Although felt fluency ratings were higher for high attractiveness exemplars in both stimulus classes, contrasts revealed that this effect of attractiveness on felt fluency was only significant in patterns, $F(2, 61) = 21.10, p < .001, \eta_p^2 = .41$, but not in faces, $F(2, 61) = 1.68, p = .20, \eta_p^2 = .05$. Additionally, faces and patterns differed in overall felt fluency ratings, with faces receiving higher ratings than patterns, $F(1, 62) = 4.19, p = .045, \eta_p^2 = .06$. The presentation duration $\times$ attractiveness interaction was not significant $F(4.87, 302.40) = 2.04, p = .08, \eta_p^2 = .03$. This can be interpreted to indicate that fluency ratings increase with presentation duration in faces and patterns. Additionally, only for the patterns, more attractive stimuli were also perceived as being more easily to process.

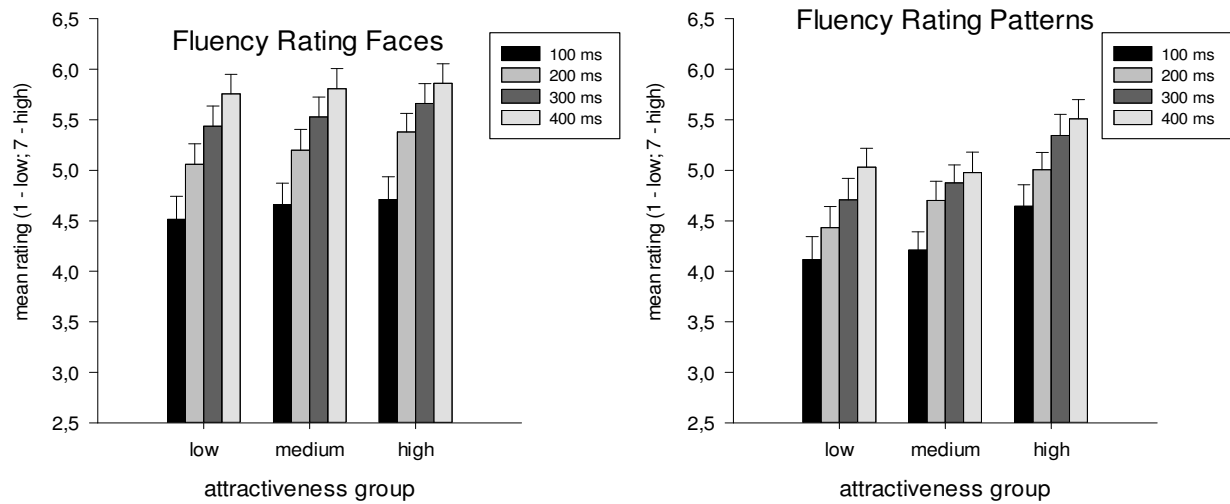


Figure 1: Fluency ratings for faces and patterns separately for presentation duration and beauty group. Error bars represent 1 SE.

Liking

Whether longer presentation durations also increase liking, as expected by the fluency account, was tested in a mixed ANOVA (stimulus class $\times$ attractiveness $\times$ presentation duration). While the main effect of presentation duration, $F(3, 186) = 1.18, p = .32, \eta_p^2 = .02$, was not significant, a significant stimulus class $\times$ presentation duration interaction, $F(3, 186) = 10.61, p < .001, \eta_p^2 = .15$, indicated differences between stimulus classes. Figure 2 shows that liking increased with presentation duration for patterns while the opposite effect was observed for faces. Planned contrasts showed that both effects—the increase for patterns, $F(3, 60) = 4.20, p < .01, \eta_p^2 = .17$, as well as the decrease for faces, $F(3, 60) = 4.73, p < .01, \eta_p^2 = .19$ —were significant.

A significant main effect of attractiveness, $F(1.77, 171.86) = 94.04, p < .001, \eta_p^2 = .60$, reflected our pre-classification in the high, medium, and low attractiveness groups. No other effects were significant (stimulus class: $F(1, 62) = 0.05, p = .82, \eta_p^2 < .01$, attractiveness $\times$ stimulus class: $F(1.21, 75.71) = 0.57, p = .48, \eta_p^2 = .01$, attractiveness $\times$ presentation duration: $F(5.56, 344.59) = 0.96, p = .45, \eta_p^2 = .02$, attractiveness $\times$ stimulus class $\times$ presentation duration: $F(5.56, 344.59) = 0.92, p = .47, \eta_p^2 = .02$). Thus, the effect of

presentation duration on the liking ratings depended on stimulus class: For patterns liking increased with presentation duration, for faces it decreased.

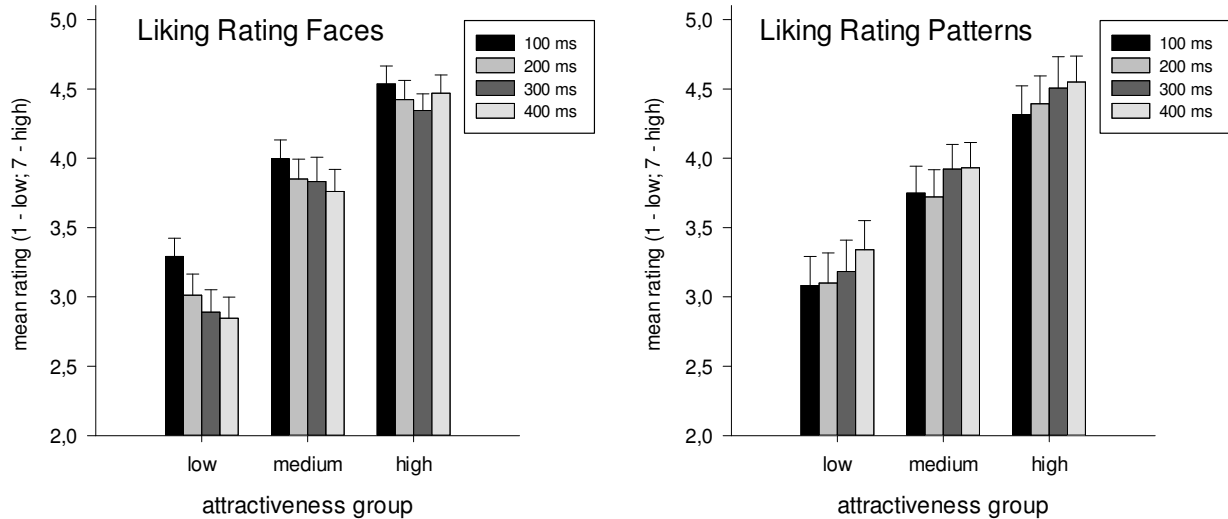


Figure 2: Liking ratings for faces and patterns separated by presentation duration and beauty group. Error bars represent 1 SE.

Certainty

The certainty results were very similar to the felt fluency results. Certainty increased with presentation duration, $F(1.68, 103.88) = 23.60, p < .001, \eta_p^2 = .27$. There was also a trend for a duration $\times$ stimulus class interaction, $F(1.68, 103.88) = 3.06, p = .06, \eta_p^2 = .05$. Overall, certainty ratings increased with presentation duration for both patterns, $F(3, 60) = 3.53, p = .02, \eta_p^2 = .15$ and faces $F(3, 60) = 10.81, p < .001, \eta_p^2 = .35$ (see Figure 3).

Moreover, there was a significant attractiveness $\times$ stimulus class interaction, $F(1.72, 106.69) = 7.57, p < .001, \eta_p^2 = .11$, and the main effect of attractiveness approached significance, $F(1.72, 106.69) = 3.17, p = .054, \eta_p^2 = .05$. Contrasts showed that certainty ratings differed within the patterns, $F(2, 61) = 6.80, p < .01, \eta_p^2 = .18$, with highly attractive stimuli receiving the highest certainty ratings. For faces, certainty ratings also differed with attractiveness but participants were more certain about unattractive compared to more

attractive faces, $F(2, 61) = 3.86, p = .03, \eta_p^2 = .11$. No other effects were significant (presentation duration $\times$ attractive: $F(5.26, 326.19) = 0.70, p = .65, \eta_p^2 = .01$; presentation duration $\times$ attractive $\times$ stimulus class: $F(5.26, 326.19) = 0.54, p = .75, \eta_p^2 < .01$; and stimulus class: $F(1, 62) = 3.03, p = .09, \eta_p^2 = .05$).

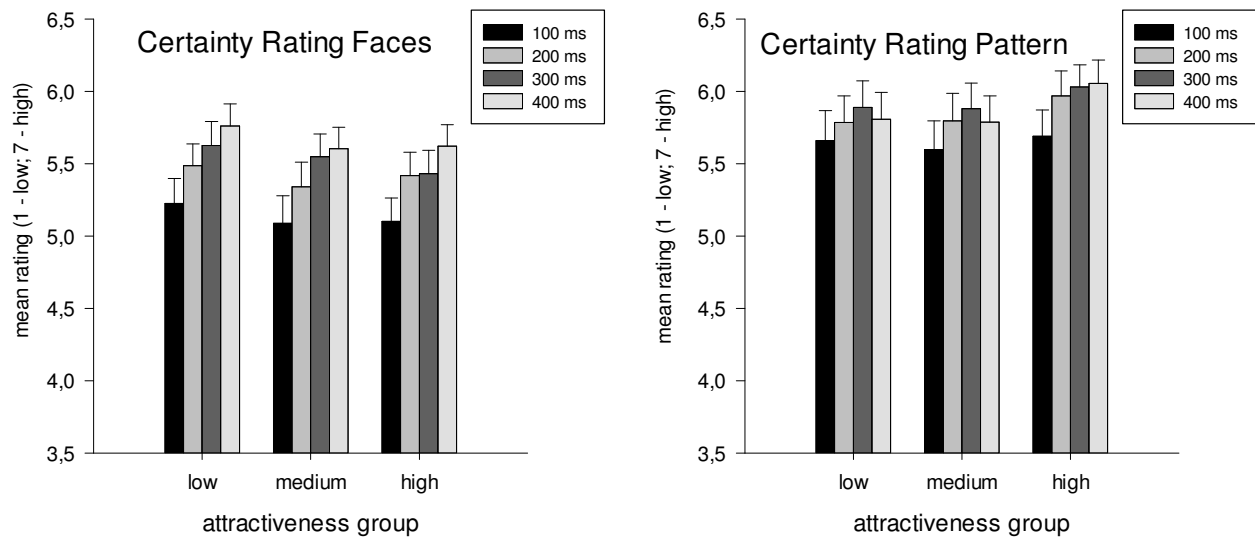


Figure 3: Certainty ratings for faces and patterns separately for presentation duration and beauty group. Error bars represent 1 SE.

Correlations

To analyze the relationship between felt fluency and liking, we additionally performed correlation analyses among these variables on a subject-wise basis. These correlations provide a critical test whether subjectively felt fluency is associated with liking. For faces, the correlations between the mean felt fluency ratings and the mean liking ratings over all participants, performed separately for all factor combinations of presentation duration and stimulus attractiveness, ranged between $r = -.37$ and $r = .09$ (mean $r = -.07, t(11) = -1.77, p = .10$). For patterns, the correlations ranged between $r = .03$ and $r = .40$ (mean $r = .23, t(11) = 6.52, p < .001$). Comparing the two sets of correlations, an independent t test showed a significantly larger correlation for patterns as compared to faces; $t(22) = 5.61, p < .001$. For patterns the correlation was positive and significantly larger than for faces. Moreover, within

the faces the correlation was near zero. Both findings are in line with the previous analyses and indicate that only for patterns higher feelings of fluency are accompanied by higher liking.

Discussion

This study tested how fluency, manipulated through presentation duration, affects liking of abstract patterns and faces. In line with fluency theory, increasing presentation durations led to higher subjectively felt fluency, certainty, and liking ratings in abstract patterns. Moreover, felt fluency significantly and positively correlated with liking. Felt fluency and certainty ratings also increased with longer presentation durations in faces. However, in contrast to fluency theory, longer presentation duration reduced liking ratings of faces. Additionally, the correlation of felt fluency and liking was near zero. Thus, higher fluency did not result in higher liking. These results indicate that fluency is not always connected to more positive stimulus evaluations (Albrecht & Carbon, 2014; Brinol, Petty, & Tormala, 2006). Fluency effects rather depended on the kind of stimulus category provided—faces or patterns.

For patterns the effects support conclusions of fluency theory. Moreover, the increase in liking was very similar among the low, medium, and high attractive patterns suggesting that fluency—at least in abstract patterns—is linked to positive experiences. This replicates previous studies showing fluency effects for rather simple or artificial categories (Gerger et al., 2011; Reber et al., 1998; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006). Additionally, our analysis showed that subjectively felt fluency influenced liking. Although the size of the mean correlation was small ($r = .23$) this replicates and extends Forster et al.'s (2013) results, which have shown that felt fluency is a determinant of liking. This small correlation also implies that factors other than felt fluency influence liking – e.g., in Forster et

al., the subjective feeling but also the objective manipulation of fluency through presentation durations influenced liking, with felt fluency being the stronger factor.

The effects were, however, quite different for faces. Increasing presentation durations decreased liking. This replicates previous research (Rashidi et al., 2012). Critically, our research extends these findings by showing that manipulations in presentation durations increased felt fluency, but this fluency signal was not used for the liking judgment as suggested by the near zero correlations. From this pattern of results the following explanations for the absence of a fluency effect can be ruled out.

First, it does not appear that discounting led to reduced liking in faces, which happens when participants become aware about the source of fluency manipulation (Bornstein & D'Agostino, 1994). Using a more subtle variation in presentation durations compared to previous studies (Gerger et al., 2011; Rashidi et al., 2012)—which reduces the chance of discounting—led to the very same direction of effects: Faces were liked less when seen for longer time. Additionally, the effects on felt fluency suggest that discounting does not play a role. Increasing presentation durations led to very similar increases in felt fluency in both stimuli classes. If discounting had occurred, we would have expected liking ratings in patterns to be affected in a similar fashion as in faces. Second, the similar change in felt fluency in both stimuli classes clearly refutes the assumption of presentation durations resulting in different fluency experiences among the two stimuli types. Thus, an absence of change in experienced fluency cannot account for the different liking effects observed in faces. Third, the near zero correlations of felt fluency and liking showed that felt fluency did not affect liking in faces.

Interestingly, it is a robust finding that other fluency enhancing factors like averageness, symmetry, and familiarity (Halberstadt, Pecher, Zeelenberg, Wai, & Winkielman, 2013; Halberstadt & Rhodes, 2003; Reber et al., 2004; Winkielman et al., 2006)

increase facial attractiveness (Little et al., 2011; Thornhill & Gangestad, 1999; Tinio et al., 2013). On a neuronal level, Trujillo, Jankowitsch, and Langlois (2014) demonstrated that highly attractive faces which conform more to a facial average (Potter & Corneille, 2008) and are more symmetrical (Grammer & Thornhill, 1994) are easier to process. These faces are categorized faster and demand less cognitive resources as indicated by a reduced N170 ERP component. Hence, attractive compared to unattractive faces in our study should also have been perceived as easier to process. Increases in felt fluency due to higher attractiveness were, however, not substantial (see Figure 1), evidently because not all cognitive processes are available to conscious report. In Topolinski and Strack (2009) fluency, varied by semantic coherence, was not available to conscious report but nonetheless influenced liking. Still, presentation duration manipulations affected felt fluency ratings of faces, but were also not related to liking. Thus, in our study felt fluency in faces was not used as source for liking.

We would suggest that some factors other than fluency then could have attributed to liking of faces in our study. For example, Hansen and Topolinski (2011) have demonstrated that the otherwise positive effect of averageness can be reversed by task demands. In an exploratory mindset less fluent novel dot patterns are preferred over average dot patterns because they serve the exploratory function of being less familiar. Similarly, it is suggested that facial attractiveness serves the evolutionary function of signaling successful adaptation to environmental pressures, genetic, and reproductive fitness thereby selecting fitter individuals (Gerger & Leder, 2014; Little et al., 2011; Thornhill & Gangestad, 1999). Our experimental manipulation of presentation durations might have affected factors that relate to such evolutionary function of facial attractiveness.

Particularly, longer durations allow processing stimuli in greater detail and depth (Fei et al., 2007; Mackworth, 1963) and different aspects of a stimulus become diagnostic for its liking (Thielsch & Hirschfeld, 2012). Varying presentation durations from 50 ms to up to

10000ms Thielsch and Hirschfield found that liking in short durations relies more on low spatial frequency information compared to the more detailed high spatial frequency information. Low spatial frequency information can be understood as a blurring filter – e.g., much like applying make-up to a face (Osborn, 1996) – which preserves overall configural information (averageness, symmetry) but reduces the impact of facial details (bad skin condition, blemishes, wrinkles, unevenness). Such facial details can reduce attractiveness to considerable extent as they imply less fit individuals (Fink, Bunse, Matts, & D'Emiliano, 2012). Additionally, as facial attractiveness is a multidimensional construct (Cunningham et al., 2002) comprising perceptual, experiential, sexual, and social factors, this complex set of appraisals might have diminished the influence of fluency. In other words, faces might have been liked more at shorter presentation durations, because the duration was too short to perceive specific unattractive features. On the other hand, for abstract patterns, where liking mainly depends on configural aspects of symmetry and complexity but not on complex appraisals or functional explanations, shorter presentation duration lead to a less accurate and fluent perception which then negatively affected liking (Reber et al., 2004).

The above conclusions are in line with the framework of Unkelbach and Greifeneder (2013). In order for fluency to affect judgments three steps have to be fulfilled. First, fluency has to be experienced by the perceiver. This was the case for both stimulus classes in our study. Second, fluency must be attributed to the judgment and not discounted to another source. Our data support the conclusion of discounting not affecting judgments. Critically, fluency also must be interpreted within the context of the judgment in the last step. Here, as providing liking ratings in faces (compared to patterns) engenders a very specific context, linked to evolutionary functions, fluency was disregarded for liking.

We also assessed certainty ratings about the liking decision. In line with fluency theory, certainty increased with longer presentation duration for both types of stimuli.

Additionally, in patterns participants were most certain about liking decisions of highly attractive examples. On the contrary, in faces, participants were most certain about liking decisions for low attractiveness. This result might reflect an avoid-the-worst strategy (Zebrowitz, Fellous, Mignault, & Andreoletti, 2003; Zebrowitz & Rhodes, 2004) as attractiveness is linked to fitness related information (Gerger & Leder, 2014; Little et al., 2011), with unattractive faces signalling poor fitness. Hence, spotting less fit individuals with high certainty might be beneficial in evolutionary terms.

Conclusions

In sum our results challenge the view that higher fluency is always associated with positive outcomes (see also, Albrecht & Carbon, 2014; Brinol et al., 2006; Unkelbach & Greifeneder, 2013). These results demonstrate the special status faces have with regard to human perception and evaluation. Thus, although we may be fascinated by a person at first sight, this study suggests that interesting effects may accompany a second look.

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Summary & Outlook

By testing how liking of faces, varying in attractiveness, is affected by manipulations of ease-of-processing we showed that previous findings indeed hold (Gerger et al., 2011; Rashidi et al., 2012). In contrast to typical effects of fluency, liking of faces decreased with longer presentation duration. Certainty and felt fluency ratings, on the other hand, showed typical fluency effects. The longer the stimuli were presented the higher the felt fluency and the more certain participants were in their liking evaluations.

From our findings we can exclude at least three possibilities for the reversal of fluency effects on liking of faces. First, felt fluency ratings showed an increase with longer presentation duration and thus higher ease-of-processing. Therefore, we can exclude the possibility that liking decreased because faces felt less fluent with longer presentation durations. Second, the results for abstract patterns showed the expected effects of fluency—an increase in liking, certainty, and felt fluency with longer presentation durations. Thus, the manipulation was suitable for eliciting effects of fluency. Third, all results of patterns and the results of felt fluency and certainty in faces render it unlikely that discounting effects can explain the effect in faces. Previous research suggests that high awareness of the ease-of-processing manipulation leads to discounting of fluency as a source of evaluations (Bornstein & D'Agostino, 1992, 1994). If discounting had been an issue in our design, fluency should have been discounted with abstract patterns as well.

From our findings, we can only speculate why liking of faces decreased with longer presentation durations. Previous findings have shown that the interpretation of fluency can be reversed by feedback learning (Unkelbach, 2007). However, as we did not give any feedback about the interpretation of fluency, this explanation seems unlikely. What is more likely is that only longer presentation durations allowed processing in more detail (Fei-Fei, Iyer, Koch, & Perona, 2007) and different aspects of the stimulus are considered (Thielsch & Hirschfeld,

2012). Thus, it might be that only at longer presentation durations the unattractive features of faces, such as blemishes, wrinkles, or bad skin condition, become apparent. Thus, regardless of the attractiveness of the face, the longer it is presented the less it is liked. In future studies this hypothesis could be tested by explicitly manipulating these unattractive features while measuring eye-movements and ratings of specific unattractive features.

Regarding the predictions on liking due to different levels of attractiveness, none of the accounts could fully explain the present findings. In light of a decrease in liking for faces, the claim that fluency is inherently positive seems not to hold, at least for faces. The results for abstract patterns, however, are well in line with hedonic marking of fluency (Winkielman et al., 2003). Regardless of predefined attractiveness, liking increased with higher ease-of-processing. Accounts of processing fluency as an unspecific activation (Bornstein & D'Agostino, 1994; Mandler et al., 1987) or as an amplifier of emotional valence (Albrecht & Carbon, 2014) would predict effects depending on the attractiveness level of faces. As effects neither for faces nor for abstract patterns varied with attractiveness, these two accounts are not compatible with our findings.

Taken together, the results highlight the special status of faces in human perception. The practical consequence of our findings is: though a person might look attractive at first glance, taking another look might be warranted to really evaluate how attractive the person is.

General Discussion and Outlook

As presented in the introduction, there are several accounts vying for the explanation of processing fluency. The accounts leave a number of empirical questions open, especially regarding the transition from fluency to evaluation. In this thesis, I thus addressed how the ease of visual processing is experienced as a feeling of fluency and how this feeling of fluency affects the evaluations of objects in terms of liking. As presented in Publication 3, the current findings together with the state-of-knowledge about processing fluency led to the formulation of an own model of processing fluency (see Figure 2).

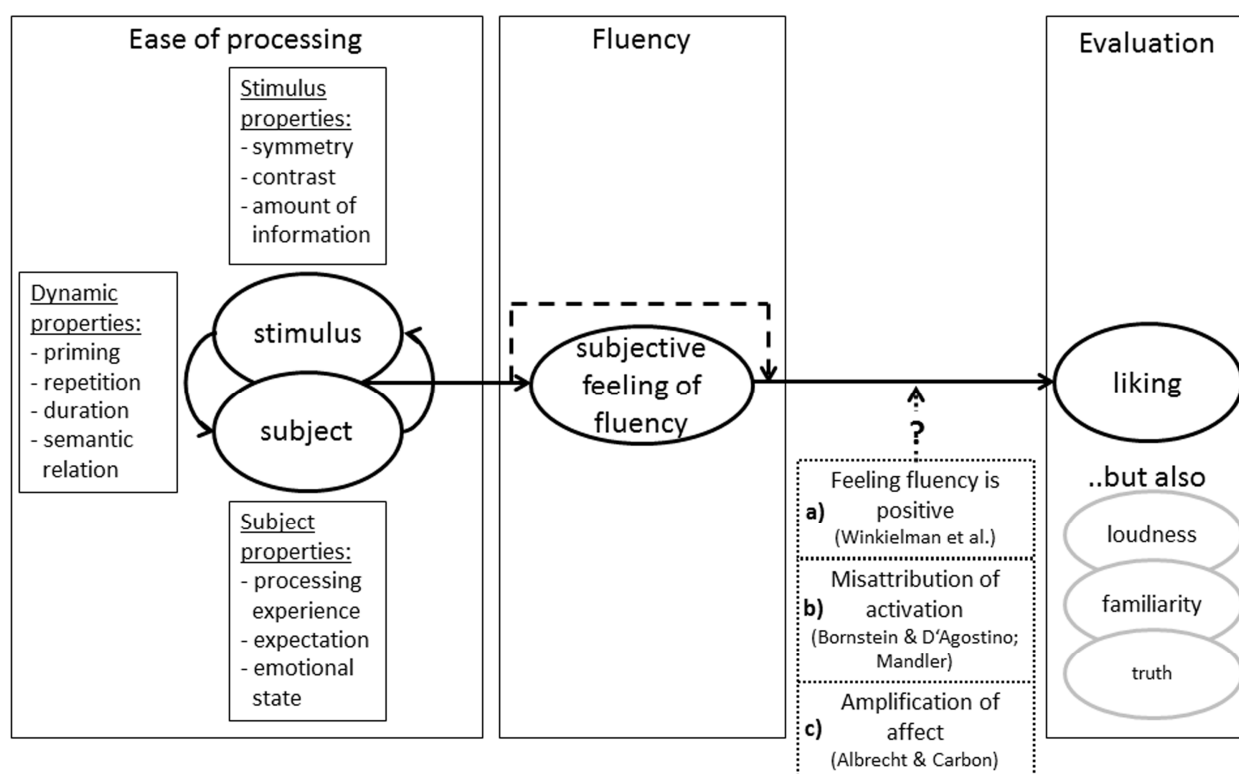


Figure 2: Schematic model of processing fluency (image taken from Forster, Fabi, & Leder, 2015)

Our contributions show that individuals have an idea of how easy information can be processed—a subjective feeling of fluency (especially addressed in Publications 2 and 3, see Fig. 2). In all contributions, higher ease-of-processing led to stronger feelings of fluency. Thus, this represents first empirical evidence that the subjective feeling of fluency is an inherent part of processing fluency. Our findings furthermore show that the feeling of fluency

is consciously accessible and that conscious experience of fluency is not detrimental for the effect (Bornstein & D'Agostino, 1994). To account for this finding, in our model the subjective feeling of fluency directly follows from ease-of-processing. Nonetheless, previous research has shown that ease-of-processing can influence evaluations without a conscious feeling of fluency (Reber et al., 2002b; Topolinski & Strack, 2009c). Furthermore, in Publication 2 we found effects on liking of both the actual manipulation of ease-of-processing and the feeling of fluency. In our model this possibility is indicated with a dashed line from ease-of-processing to evaluation, circumventing the feeling of fluency.

Moreover, we showed that this feeling is rather robust across variations in experimental context. Feelings of fluency were influenced regardless of whether ease-of-processing was varied within- or between-participants (Publication 1). Even when the ease of processing varied between two groups of participants, feelings of fluency differed. This indicates that the ease-of-processing in an interaction between a stimulus and a subject (see Fig. 2, left), for example a person looking at an artwork, can most probably be evaluated on an absolute level, possibly in reference to a personal norm or standard. This evaluation seems to be uninfluenced by the origin of ease-of-processing (for possible sources of fluency see Fig. 2, left). In Publication 1, both variations, clarity and presentation duration, led to higher feelings of fluency. Interestingly, liking was influenced only in the within-participants manipulation of ease-of-processing. This might be due to the higher salience of the feelings when ease-of-processing varied among the stimuli.

The term “feeling” suggests that the experience of fluency has an affective component. A notable question among the accounts of processing fluency is whether the feeling of fluency is affectively positive (Reber, Schwarz, et al., 2004; Winkielman et al., 2003) or affectively unspecific (Bornstein & D'Agostino, 1992, 1994). Indeed, participants seem to use the feeling of fluency as a source for especially positive evaluations of the

stimuli. Nonetheless, we could not find clear physiological reactions to higher ease-of-processing. This indicates that this feeling might be more of an experience of the cognitive processes than a strong affective reaction (Article 4, see also Greifeneder & Unkelbach, 2013). As indicated in Figure 2, it is still not fully clear how feelings of fluency influence evaluations. Each explanation—fluency is affectively positive (Reber, Schwarz, et al., 2004; Winkielman et al., 2003), fluency is unspecific (Bornstein & D'Agostino, 1992, 1994), fluency amplifies affect (Albrecht & Carbon, 2014)—is backed by empirical evidence. Possibly, subtle differences in the task demands or the design might have promoted different effects in the respective studies. Thus, depending on the context fluency might be either positive, unspecific, or amplifies affect. Thus, future research should more directly compare the general conditions under which fluency promotes which of the effects.

In line with previous research, we used quite simple stimulus material in the first four contributions. By using more complex stimuli, namely artworks and faces, we tested the limits of the fluency-liking link. Ambiguous (disfluent) artworks were preferred over non-ambiguous (fluent) artworks when participants had enough time to indulge in the challenge of ambiguity (Publication 5). Furthermore, liking of faces decreased with increasing fluency (Publication 6). Thus, with more complex stimuli, fluency is but one source for liking (Leder et al., 2004; Leder & Nadal, 2014).

Apart from answering the initially raised questions about the transition from fluency to evaluation, the contributions give further insight into processing fluency. From our experiments, we can claim that consciously experiencing fluency does not lead to discounting. In all our contributions, our participants were able to perceive variations in ease-of-processing (presentation duration varying among 100, 200, 300, and 400 ms). Furthermore, in Publication 3 we presented participants with false feedback about their putative ease-of-processing. Despite this direct feedback, we found effects of ease-of-processing on feelings of

fluency and on evaluations. Thus, as long as the experiment does not explicitly give a clear alternative explanation for feelings of fluency (Schwarz et al., 1991), conscious experience of fluency is not detrimental for fluency effects.

There are at least two limitations to the presented findings. First, we predominantly used variations in presentation duration to manipulate ease-of-processing, following previous research, because this showed robust effects. Also other manipulations of perceptual fluency, such as contrast or font readability (Reber et al., 1998; Reber, Wurtz, et al., 2004), show similar effects. This is also shown in Publication 2, where we additionally manipulated ease-of-processing via subliminal contour priming. Furthermore, previous research has shown that manipulations of conceptual fluency, such as semantic coherence (Topolinski & Strack, 2009a; Whittlesea, 1993), show similar effects to what is present here. This is also reflected in Publication 5, where we compared ambiguous and non-ambiguous artworks, showing that ambiguity can be seen as a manipulation of conceptual fluency.

Second, we focused on evaluations of liking. Together with familiarity and truth, liking is probably the most thoroughly researched variable in processing fluency (see Fig. 2). However, the process of fluency suggests that liking is in no way a special dimension. Fluency is said to be a cue for a number of different evaluations. Nonetheless, liking is a relevant dimension in many fields, such as social cognition (e.g., Halberstadt & Winkielman, 2014; Ke, Lin, & Cai, 2011), empirical aesthetics (e.g., Reber et al., 1998), or consumer research (e.g., Labroo et al., 2008; Landwehr et al., 2011; Lee & Labroo, 2004). Furthermore, studying liking allows testing of a main controversy regarding whether fluency leads to more positive ratings as opposed to just higher ratings (Albrecht & Carbon, 2014; Bornstein & D'Agostino, 1994; Mandler et al., 1987; Reber et al., 1998). Our findings have shown that higher fluency indeed leads to more *positive* ratings, and not just generally *higher* ratings (but see Albrecht & Carbon, 2014).

One fruitful avenue for future research would be to further study the characteristics of the dimensions that are evaluated. It is possible that liking, familiarity, and truth are susceptible to processing fluency, because other characteristics of the stimuli are not diagnostic. In research on familiarity and truth, fluency effects only occur when decisions whether the stimuli/statements are familiar or true are difficult (Dechêne et al., 2010). For easily remembered stimuli and easy statements participants do not need fluency to evaluate familiarity or truth (see Wagner & Gabrieli, 1998, for a discussion). Thus, liking might be especially influenced by processing fluency when individuals are uncertain about their evaluations. This importance of uncertainty has however not yet been empirically shown.

Third, all our contributions, as well as previous research have clearly shown that higher processing fluency leads to higher liking. However, a common objection is that liking might as well influence processing fluency. Monin (2003), for example, could show that liking leads to higher familiarity. Following the above described models, processing fluency stemming from higher ease-of-processing is said to be an activation (be it positive or unspecific), which is then used as a cue for evaluations (Unkelbach & Greifeneder, 2013). The reversed process would suggest that liking stemming from something else is used as a cue for higher ease-of-processing. Constable, Bayliss, Tipper, and Kritikos (2013), however, show that impressions of preference do not lead to higher fluency (but see Ramsøy & Skov, 2014). A thorough examination of the process has to experimentally manipulate the liking and then study its effects on feelings of fluency. One way of manipulating liking might be through giving false feedback, as successfully applied in Forster et al. (2015).

Together, this thesis' publications show that higher ease-of-processing is reflected in a feeling of fluency, which is then used as a cue for evaluations of liking. Based on this evidence what is in store for future research on processing fluency and liking? The last two publications using artworks and faces indicate the multifactorial nature of liking evaluations.

How much we like something is influenced by fluency, but also by a multitude of other factors, such as personal relevance, taste, social factors, or expertise (Leder et al., 2004; Leder & Nadal, 2014). This leaves the question open how strong the influence of fluency is compared to other factors. Depending on the type of stimulus that is evaluated some factors might contribute more to the evaluation than others. Thus, the different findings might have been promoted by different stimulus classes that were used in the experiments. When stimuli are simple (e.g., line drawings in Forster et al., 2015; Forster et al., 2013; Reber et al., 1998) or devoid of meaning (e.g., dot patterns in Reber et al., 1998), processing fluency might be the only source for evaluations. With more complex and more relevant categories such as faces or artworks the above mentioned factors of personal taste or expertise also contribute to evaluations. Thus, future research should address the exact contribution of processing fluency in liking ratings. This would also contribute to models in empirical aesthetics (e.g., Leder et al., 2004; Leder & Nadal, 2014), in which processing fluency is one of the factors described as influencing aesthetic appreciation. Regarding models of aesthetic appreciation one could study whether processing fluency is attenuated or completely disregarded as a source for evaluating more complex stimuli. Given that it is possible to assign weights to all factors in those frameworks, ultimately it might become possible to model and predict aesthetic appreciation.

Assessing the weight of processing fluency in the process of liking is furthermore of importance for applied fields. If for more complex stimuli the effect of fluency on liking is substantial then practical applications should focus on the ease-of-processing. If, however, the effect of fluency on liking is negligible then effort should be rather directed to those factors that are more strongly influencing liking. In this respect the findings of empirical studies will be useful for designers (see for example Leder, Forster, & Gerger, 2011).

Certainly, experiencing fluency is a cue for evaluations of objects when there is little other information present, when the situation is unclear, or when fast decisions are needed (Jakesch et al., 2013). This ability is definitely helpful in our everyday life and eventually aids our survival in an often ambiguous environment, where we need to evaluate quickly.

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Appendix

Zusammenfassung

Die Einfachheit der Verarbeitung eines Reizes, auch Verarbeitungsflüssigkeit (engl. processing fluency) genannt, kann eine Vielzahl an Bewertungen des Reizes beeinflussen. Was einfacher zu verarbeiten ist, wird als bekannter, wahrer, aber insbesondere als gefälliger eingeschätzt (siehe Alter & Oppenheimer, 2009b, für einen Überblick). Zahlreiche Studien belegen, dass die Verarbeitungsflüssigkeit als Quelle für Bewertungen herangezogen wird. Darüber hinaus wurden mehrere Modelle formuliert, die versuchen den Prozess der Verarbeitungsflüssigkeit theoretisch darzustellen. Trotzdem sind zentrale Fragen zum genauen Ablauf ungeklärt. Insbesondere über die subjektive Erfahrung der Verarbeitungsflüssigkeit, also über das Gefühl der Flüssigkeit, ist wenig bekannt. Alle Modelle postulieren, dass auf verschiedenen Stufen der Wahrnehmung eine höhere Verarbeitungsleichtigkeit in einer höheren Flüssigkeit resultiert. Diese Flüssigkeit wird dann als Quelle für Bewertungen benutzt. Die Modelle unterscheiden sich jedoch in mehreren zentralen Punkten: Erstens ist es unklar, ob die Erfahrung der Flüssigkeit bewusst wahrnehmbar ist, also ob es ein Gefühl der Flüssigkeit gibt (Reber et al., 2002b) und wenn ja, ob die bewusste Wahrnehmung der Flüssigkeit den Effekt abschwächt (Bornstein & D'Agostino, 1992, 1994). Zweitens ist unklar, ob das Gefühl der Flüssigkeit affektiv positiv (Winkielman et al., 2003) oder einfach eine affektiv unspezifische Aktivierung (Bornstein & D'Agostino, 1992, 1994) ist. Sechs Beiträge (dabei insbesondere Artikel 2 und 3) zeigen, dass das Gefühl der Flüssigkeit sehr wohl bewusst wahrnehmbar ist und dass die bewusste Wahrnehmung keineswegs negative Auswirkungen auf das Gefühl der Flüssigkeit hat. In Artikel 4 wurde gezeigt, dass das Gefühl der Flüssigkeit insbesondere für positive Bewertungen der Reize benutzt wird. Jedoch ist dieser Effekt nur sehr subtil in physiologischen Reaktionen reflektiert. Dies weist darauf hin, dass die

Verarbeitungsflüssigkeit eher das Erleben von kognitiven Prozessen als eine starke affektive Reaktion ist (siehe auch Greifeneder & Unkelbach, 2013). Trotzdem ist das Gefühl der Flüssigkeit sehr robust gegenüber Variationen im Versuchsaufbau. In Artikel 1 konnte gezeigt werden, dass das Gefühl der Flüssigkeit resultiert, unabhängig davon ob die Manipulation der Einfachheit der Reize innerhalb des Experiments oder zwischen den Personen variiert. Das weist darauf hin, dass Personen absolut, also ohne einen Vergleichsmaßstab, einschätzen können wie einfach die Verarbeitung ist. Anhand von komplexeren Reizmaterials (Gesichter und Kunstwerke), konnten wir die Grenzen des Zusammenhangs zwischen Flüssigkeit und Gefallensbewertungen zeigen. Mehrdeutige, also wenig flüssige, Kunstwerke gefallen dann mehr als eindeutige, flüssige Kunstwerke, wenn Personen genug Zeit haben um die Mehrdeutigkeit zu verarbeiten und zu lösen (Artikel 5). Weiters zeigt sich, dass mit einem Anstieg der Flüssigkeit Gesichter weniger gefallen (Artikel 6). Diese Ergebnisse weisen darauf hin, dass in unserem täglichen Umgang mit Reizen die Verarbeitungsflüssigkeit nur eine von vielen Quellen für unsere Gefallensbewertung ist (siehe auch Leder et al., 2004; Leder & Nadal, 2014). In Summe bestätigen die Ergebnisse dieser Dissertation klar, dass die Verarbeitungsflüssigkeit eine Quelle für unsere Bewertungen von Reizen ist. Insbesondere wenn die Wahrnehmung erschwert ist, also wenn mit nur wenig vorhandener Information Entscheidungen getroffen werden müssen, dann ist die Flüssigkeit ein wichtiger Hinweis für Bewertungen. Der spezielle Beitrag dieser Dissertation zum Stand der Forschung ist, dass die bewusste Wahrnehmung der Gefühle der Flüssigkeit möglich ist und dass diese keineswegs problematisch für den Effekt der Flüssigkeit auf Bewertungen ist.

Curriculum Vitae

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PUBLICATIONS

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Forster, M., Fabi, W., & Leder, H. (2015). Do I really feel it? The contributions of subjective fluency and compatibility in low-level effects on aesthetic appreciation. *Frontiers in Human Neuroscience*, 9:373. doi: 10.3389/fnhum.2015.00373

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Leder, H., Forster, M., & Gerger, G. (2011). The glasses stereotype revisited: Effects of glasses on perception, recognition and impressions of faces. *Swiss Journal of Psychology*, 70, 211-222. doi:10.1024/1421-0185/a000059

Other publications

Forster, M. (2014). Review of the book *The Aesthetic Brain: How We Evolved to Desire Beauty and Enjoy Art*, by A. Chatterjee. *Psychology of Aesthetics, Creativity, & the Arts*, 8, 260-261. doi:10.1037/a0036401

Forster, M., Gerger, G., & Leder, H. (2013). The glasses stereotype, revisited. *The Jury Expert*, 25, 1-9.

Invited Talks

Forster, M. (2013). *Processing fluency and liking*. Invited talk at the University of York, UK, (09.2013).

Conference Contributions

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Forster, M., Fabi, W., & Leder, H. (2014). *Subjective fluency influences liking*. Talk presented at the 56th Conference of Experimental Psychologists (TeaP), Gießen, Germany.

Forster, M., Gerger, G., Jakesch, M., & Leder, H. (2013). *Fluency needs uncertainty*. Talk presented at the 18th Meeting of the European Society for Cognitive Psychology (ESCOP), Budapest, Hungary.

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Nadal, M., Forster, M., Paul, M., & Leder, H. (2013). *Looking at images with an aesthetic orientation: What's special about it?* Poster presented at the 36th European Conference on Visual Perception (ECVP), Bremen, Germany.

Forster, M., & Leder, H. (2013). *Subjective fluency and affective response*. Talk presented at the 55th Conference of Experimental Psychologists (TeaP), Vienna, Austria.

Forster, M., Leder, H., & Ansorge, U. (2012). *Subjective feeling of fluency and affective response*. Poster presented at the 35th European Conference on Visual Perception (ECVP), Alghero, Italy.

Forster, M., & Leder, H. (2012). *Mirror reversal of artworks*. Talk presented at the 1st Visual Science of Art Conference (VSAC), Alghero, Italy.

Forster, M., & Leder, H. (2012). *Subjective fluency and aesthetic preference*. Talk presented at the 54th Conference of Experimental Psychologists (TeaP), Mannheim, Germany.

Forster, M., Leder, H., & Gerger G. (2011). *Perceiving faces with different kinds of glasses: Distinctiveness, beauty and intelligence*. Poster presented at the 17th Meeting of the European Society for Cognitive Psychology (ESCOP), Donostia - San Sebastián, Spain.

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Diploma Thesis

Forster, M. (2010). *Topografische Relevanzfeldkarten im Autoinnenraum: Untersuchung zentraler Bereiche durch haptische Evaluation*. [Topographical maps of relevance fields: Exploration of relevant areas using haptic evaluation]. Unpublished Diploma Thesis, University of Vienna, Austria.

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