universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master‘s Thesis

„It felt disfluent so I remembered it? Effect of visual disfluency on recognition memory“

verfasst von / submitted by

Markus Roman Tünte, BSc

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2019 / Vienna 2019

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 840
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Psychologie UG2002
Betreut von / Supervisor:	Univ.-Prof. Dipl.-Psych. Dr. Helmut Leder
Mitbetreut von / Co-Supervisor:	-

Table of Content

Abstract

Recently, researchers have started to explore the impact of disfluency, as opposed to fluency, investigating the consequences of hard to process stimuli. Disfluency has been proposed to increase memory for a stimulus by directing increased attentional resources to it. Most research in this area has been conducted using word stimuli and dichotomous fluency contrasts. Few empirical approaches have investigated underlying cognitive mechanisms of a disfluency-memory effect. Cognitive control processes have been proposed to be such a potential underlying mechanism. However, null-findings have cast doubt on the effect in general. The present thesis explored the impact of visual contrast manipulations of simple photographs on performance in fluency- and disfluency-memory paradigms and its relation to individual ability in cognitive control operationalized by a Stroop task. Results showed that although traditional fluency effects were found, no positive impact of disfluency on memory performance in a surprise recognition paradigm could be established. Moreover, the strongest negative contrast manipulation impaired memory performance compared to all other contrast manipulations. No correlation between individual abilities of cognitive control and (dis)fluency were found. The findings question theoretical accounts that propose a positive effect of disfluency on memory performance and suggest that related findings might be false positives. Applying disfluency manipulations as a mean for learning should thus be taken with caution, especially in the case of visual stimuli.

Introduction

Fluency theory proposes that if a stimulus (e.g., a painting) is processed with metacognitive ease it is accompanied by positive affect (e.g., Alter & Oppenheimer, 2009; Reber, Schwarz, & Winkielman, 2004). Fluency paradigms usually contrast an easy to process stimulus (fluent condition) with a hard to process one (disfluent condition). Traditional fluency approaches focus on the advantages of fluent compared to disfluent stimuli, with findings indicating that fluent stimuli are liked more, judged as more familiar, or as easier to learn (Koriat & Ma'ayan, 2005; Westerman, Lanska, & Olds, 2015). Recently however, scientists have turned their attention towards disfluency and its impacts, exploring the consequences of hard to process stimuli. Some results have found that in memory paradigms disfluent stimuli are recalled with greater accuracy than fluent ones, indicating that disfluency can be beneficial for recall (Alter, 2013).

Take for example a recent study: researchers asked participants to view 4 to 5 letter words and to give judgements of learning (JoL) – how well the stimulus could potentially be remembered in the future (Besken & Mulligan, 2013). Words were either just presented for 2500ms (fluent condition) or for 83ms followed by a row of Xs for 2417ms (disfluent condition). Later in the experiment participants engaged in a memory paradigm that contrasted previously encountered words with novel ones. Results indicated that although participants JoLs were more confident for the fluent condition, during the subsequent memory-test, disfluent stimuli were recalled with higher accuracy, revealing a double dissociation between predicted metamemory and actual recall.

Disfluency Memory Effects

Two main theoretical accounts have been discussed to explain such disfluency-memory effects. On the one hand, traditional disfluency accounts attribute the disfluency-memory effect to additional attentional resources needed for processing (Alter, Oppenheimer, Epley, & Eyre, 2007). Such theories base on the idea of dual processing systems (also see Kahneman, 2012). One, which is fast and automatic (System 1) and one, which is slow and deliberately (System 2). Fluency is believed to activate System 1, while disfluency activates System 2. This in turn yields better memory encoding for disfluent stimuli as enhanced attentional resources are activated.

According to the desired difficulties account (Bjork & Bjork, 2011) on the other hand, a certain difficulty in processing might be beneficial for memory encoding. This view builds on a number of observations that for humans a distinction between performance in a certain task and later recognition memory can be observed (Bjork, 1994). That is, simply enhancing performance during training or encoding does not lead to optimal performance in retrieval of information. In other words, being able to solve a task fast and easy is great for performance at the moment of task performance, but not for later recognition. A positive impact on retrieval can be gained through the introduction of desired difficulties at the cost of negatively impacting performance.

However, not all difficulties are desired for improved recognition memory. This implies that making a task too hard can negatively impact recognition memory. For example, a recent experiment using a disfluency-memory paradigm found that too hard to process stimuli negatively impact memory retrieval as blurring words in a memory experiment beyond a certain point eliminated any memory effect previously found (Experiment 4; Rosner, Davis, & Milliken, 2015).

Disfluency and Cognitive Control: A possible underlying cognitive mechanism

Building up on traditional (dis)fluency- and the desired difficulties approach, a third approach focusing more on underlying cognitive mechanisms has been discussed recently to explain a potential effect of disfluency on recognition memory (Rosner et al., 2015). In more detail recent research has found that in situations requiring cognitive control improved recognition memory can be observed (Krebs, Boehler, De Belder, & Egner, 2013; Richter & Yeung, 2012). For example, using a face-word Stroop task Krebs et al. (2013) found that participants showed greater surprise recognition memory for faces presented in incongruent conditions (e.g., female faces overlaid with the word male) compared to ones presented in congruent conditions (e.g., female faces overlaid with the word female). This finding was explained by increased cognitive control during incongruent trials, thus resulting in utilization of greater attentional resources and improved encoding.

Rosner et al. (2015) point out that the finding of improved recognition memory for incongruent trials in a cognitive control task in principal is in line with the notion of desired difficulties as competition between distractor and target might represent a desired difficulty. Moreover, this finding can also be considered in line with traditional disfluency accounts which build upon the notion of two modes of processing, one fast and automatic, and one slow and deliberate (Kahneman, 2012; Oppenheimer & Alter, 2014). Incongruent trials in e.g., a Stroop task might thus use the slow processing system, resulting in greater memory encoding.

Building up on the finding of improved recognition memory for incongruent trials in a cognitive control task it can also be hypothesized that both, cognitive control-memory- and disfluency-memory-effects, share similar underlying cognitive mechanisms (Krebs et al., 2013; Rosner et al., 2015). It has been proposed that such a mechanism might be the upregulating of control during incongruent trials typically found in selective attention task (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Krebs et al., 2013; Rosner et al., 2015). This so-called conflict-monitoring account proposes that the anterior cingulate cortex (ACC) monitors incoming information for potential conflict. Upon detection of conflict, upregulation to more frontal region takes place that leads to increased top-down control of behavior (Cohen, 2017), which inter alia can result in improved memory encoding (Krebs et al., 2013). Thus, improved memory for disfluent trials might build on the same underlying cognitive process, as e.g., an incongruent Stroop trial: experienced disfluency might trigger up-regulation through the ACC (Rosner et al., 2015).

Fluency, Cognitive Control and Conflict Adaptation

Adding to the notion of conflict monitoring as a potential underlying mechanism of a disfluency-memory effect is other research that has already found parallels between traditional fluency accounts and mechanisms of cognitive control (Dreisbach & Fischer, 2015 & 2011). Combining a cognitive control- and a fluency paradigm, Dreisbach and Fischer (2011) found that (dis)fluency manipulations can lead to conflict adaption, as participants showed improved performance following disfluent trials. Conflict adaptation is usually observed in traditional cognitive control paradigms, such as a Stroop task, and refers to a strengthening of control following an incongruent trial, such that participants respond faster and more accurate, which has on a neural level been connected to activity in the ACC (Egner, 2017).

Interestingly, the ACC has also been implicated in emotional processing and resolving of emotional conflict (Braem et al., 2016; Etkin, Egner, & Kalisch, 2010). Fluency accounts in general accentuate an affective component with on the one hand ease of processing being accompanied by positive affect (Reber et al., 2004;

Westerman et al., 2015), and on the other hand disfluency accompanied by negative affect (Topolinski & Strack, 2015). It can thus be speculated that improved memory for disfluent stimuli might be a consequence of negative affective conflict resolved through the ACC and that conflict adaptation is triggered by subjective negative affective evaluation (Dreisbach & Fischer, 2015; see also Desender, Van Opstal, & Van den Bussche, 2014;).

To sum up, it has been proposed that an underlying mechanism of improved memory for disfluent trials might be an upregulation of control through the ACC (Botvinick et al., 2001; Rosner et al., 2015). Further, combining fluency and cognitive control paradigms it has been shown that (dis)fluency itself can lead to conflict adaptation (Dreisbach & Fischer, 2015). Conflict adaptation is an effect traditionally reported in cognitive control paradigms that has been connected to ACC activity (Egner, 2017). However, to date no study has directly investigated, whether an empirical connection between individual ability in cognitive control and performance on a disfluency-memory task can be found. Following approaches that have correlated individual ability of cognitive control with other constructs (De Galan, Sellaro, Colzato, & Hommel, 2014) it can therefore be hypothesized that if disfluency-memory effects can be explained by a conflict-monitoring account individual performance on a Stroop task should be correlated to individual performance on a disfluency-memory task.

Fluency and Optimal Levels of Processing: U-Shaped Relationships?

As noted earlier, fluency theories circle around the idea that if something is processed with metacognitive ease it is also accompanied by positive affect (Reber et al., 2004). For example, with a linear increase in ease of processing of a picture, a similar increase in liking ratings can be assumed. However, it has been proposed that in some instances this relationship might follow an inverted u-shaped curve (Berlyne, 1971; Reber, 2012). According to these views an optimal processing level can be identified, which then drops off as disfluency increases. Take for example visual contrast: a picture might be too hard to process if visual contrast is too low or *too high,* while in the middle some kind of optimal level exists (Figure 1). From a disfluency-memory frame of reference this would imply that more than one level of disfluency optimal for memory encoding can be hypothesized.

Figure 1. Visual contrast varied in a photograph (left: strong negative contrast, middle: original picture, right: strong positive contrast).

Still, it remains an open question if this u-shaped relationship can be adopted for a disfluency-memory effect: If disfluency enhances memory, cases with two maxima of memory performance should be identifiable. Applied to the case of visual contrast it can thus be proposed that very low and very high contrast might lead to an improved recall ability.

When proposing that a disfluency-memory effect follows a u-shape in the case of visual contrast, it is unclear how this is related to the previously proposed inverted u-shape of traditional fluency (Figure 2). Therefore, is the function of the fluency experienced during encoding (or also during retrieval) directly related to performance in a memory paradigm. If such a relationship would exist, stimuli which are experienced as disfluent during encoding should be remembered with greater accuracy than stimuli which are experienced as fluent during encoding. This in turn would imply that at least two optimal levels of visual contrast disfluency for memory encoding can be hypothesized (Figure 2). To my knowledge no study to date has contrasted more than one way of exhibiting disfluency and its impact on recognition memory in the same experiment and thus it has not been explored whether such cases can be identified.

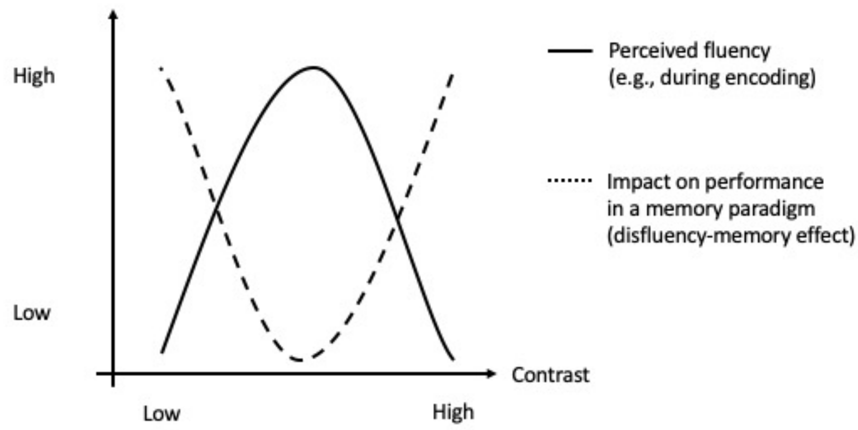

Figure 2. Proposed relationship between visual contrast and (dis)fluency: inverted u-shaped for perceived fluency, corresponding u-shape for performance in a memory paradigm.

The Influence of Fluency on Response Style

As noted previously a wide range of research has already found that stimuli perceived as fluent are also perceived as more familiar (Westerman et al., 2015; Yonelinas, 2002). Following, perceived fluency during a retrieval phase of a memory paradigm should impact performance, such as that more fluent stimuli are perceived as more familiar, leading to them being classified as previously seen, even though they might be new. In line with this notion, research investigating this relationship has found that the perceived fluency of an item in a memory paradigm itself triggers a familiarity based response style (Dew & Cabeza, 2013; Westerman, Lloyd, & Miller, 2002; Yonelinas, 2002). When an item is processed fluently, participants therefore tend to classify it as familiar, or already previously encountered, independent of whether it was seen before or not.

In signal detection theory this impacts the response bias *c*, a parameter of responding old for both old and new items (Stanislaw & Todorov, 1999; Yonelinas, 2002). The response bias is in contrast to the actual memory signal *d'* an indication of the strength of a learned association. Thus, traditionally fluency has been proposed to impact the response bias *c*, while not affecting the actual memory signal *d'*. According to more recent accounts on the other hand, disfluency should impact the actual memory signal *d'* while not impacting the response bias *c*. In line with this notion a double dissociation has been found with regard to judgments of learning and disfluency-memory performance (Besken & Mulligan, 2013). In other words, this means that there are two potential ways in which (dis)fluency can impact performance in a memory paradigm: fluency should impact the tendency to classify a stimulus as previous seen due to higher familiarity, whereas disfluency influences correctly remembering due to deeper processing.

Disfluency, Media, and Null-Findings

A potential positive effect of disfluency on recognition memory would have far-reaching consequences for learning and teaching. Maybe books and lectures should not focus on preparing a topic as clear as possible but should introduce challenges along the way. Such notion has already drawn attention of the general public. The idea of making something harder to process in order to achieve memory advantages might seem counterintuitive, but appealing, to some. For example, the Guardian (The Guardian, 2018) recently published an article praising the possible effect a font "Sans Forgetica" might have on one's ability to encode information into memory. In another instance, the earliest study to show a disfluency-memory effect (Diemand-Yauman, Oppenheimer, & Vaughan, 2011) was quickly picked up by major news outlets such as the New York Times (New York Times, 2011). By utilizing an applied classroom setting with few underlying theoretical constructs present at the time, it has to be noted that the study has drawn some criticism (e.g., Kühl & Eitel, 2016).

Further, a disfluency-memory effect in general has not been uncontroversial. Recently, 13 failed replications and/or null-findings have been published in a special issue in the journal Metacognition and Memory (see Kühl & Eitel, 2016). These highlight that a disfluency-memory effect might, if at all, only be present in certain boundaries. In addition, a recent meta-analysis that focused on a possible benefit of disfluency in educational settings also found no effect of disfluency on memory (Xie, Zhou, & Liu, 2018). With regard to the replication crisis in psychological research (Open Sciene Collaboration, 2015) failed replications and null-findings call for thorough investigation of possible effects.

Making Sense of Null-Findings and Media Hype

To sum up, some doubt has been cast on a disfluency-memory effect. On the one hand media coverage portrayed a disfluency-memory effect as the savior of overstrained students, overstating the mostly small disfluency-memory effects. On the other hand, null findings and a meta-analysis have questioned the effect in general. However, the picture painted by some accounts has to be taken with caution.

With regard to null findings (Kühl & Eitel, 2016), differing experimental protocols, which partially focused on other constructs such as working memory or cognitive load were investigated. Moreover, many null findings focused on educational outcomes in educational settings (Xie et al., 2018). While this might be a promising field of application, a potentially small memory effect could just be hard to identify in a noisy classroom setting.

Furthermore, most (if not all) experiments testing for a disfluency-memory effect use word-stimuli. However, fluency effects have been shown using a range of different stimulus classes (e.g., images, sounds; Alter & Oppenheimer, 2009) and there is no compelling reason to assume that a disfluency-memory effect only exists in the realm of word-stimuli. Also, as other authors have pointed out, certain moderating variables might additionally play an important role: increasing disfluency beyond a certain point or asking for JoLs both have been found to eliminate disfluency-memory effects (Besken & Mulligan, 2013; Rosner et al., 2015). Thus, a controlled experimental approach with stimulus classes other than words might contribute to specifying disfluency-memory effects.

Exploratory Literature Review: Defining Fluency & Memory

When investigating a possible disfluency-memory effect a number of potential moderators have been assessed. However, the definition of two core constructs, which might have been overlooked by some approaches, could be of particular importance: How to define (dis)fluency and what constitutes enhanced memory performance.

Defining (Dis)fluency. Operationalizing fluency presents researchers with a range of difficulties, as there is no direct route to it. To manipulate fluency — the metacognitive ease or difficulty with which a stimulus is processed (Alter & Oppenheimer, 2009) — a range of different variables have been used, which all may or may not be accurate indicators. Consider for a moment the case of visual contrast manipulations (Figure 1): When manipulating contrast of a stimulus one straightforward assumption is to predict that the contrast itself influences perceived fluency – medium contrast can be hypothesized to be experienced as fluent, while low- and high contrast can be hypothesized to be experienced as disfluent. However, researchers might also measure other variables that have been shown to be impacted by fluency as dependent variables, such as liking (Reber, Winkielman, & Schwarz, 1998), familiarity ratings (Westerman et al., 2015), reaction time (Schooler & Hertwig, 2005) or subjective feeling of fluency (Forster, Leder, & Ansorge, 2013). Still, none of these dependent measures represent a pure fluency account, as they might be influenced by other confounding variables.

Defining Memory Performance. Turning the focus towards memory performance, in the literature different operationalizations can be found. For example, some studies used a free recall procedures, while others used forced choice approaches (Kühl & Eitel, 2016; Xie et al., 2018). However, as fluency itself has been found to impact stimulus familiarity as well as judgments of learning (Besken & Mulligan, 2013; Westerman et al., 2015), defining memory performance in the case of disfluency has to be approached with caution. This is relevant, as fluency per definition should lead to an increased response bias, and not accounting for this in a memory paradigm gives room to a range of possible interactions that might impact a memory effect. However, in the literature for a possible disfluency-memory effect few studies have applied signal-detection theory, which controls for the impact of familiarity on memory performance. Last, a number of studies that found a positive effect of disfluency (Rosner et al., 2015), as well as of cognitive control (Krebs et al., 2013; Richter & Yeung, 2012), on recognition memory have used a surprise recognition task. In these, participants are not aware during encoding that they will have to perform a memory task later.

Research Question and Hypothesis

To sum up, disfluency, as opposed to fluency, has recently drawn the attention of researchers. Disfluency, by directing increased attentional resources to a target stimulus, is proposed to increase memory for a target. However, null-findings have cast doubt on this effect. Still, findings in this area are sparse, and more thorough investigation is needed in order to advance the field.

The experimental approach used here aims to contribute to the (dis-)fluency literature on different levels. First, to broaden the scope of a disfluency-memory effect, simple photographs of landscapes and cities will be used as stimuli instead of words. Visual contrast of the stimuli will be manipulated in two directions (positive-and negative contrast). Both, positive and negative contrast manipulations are hypothesized to be experienced as disfluent, in contrast to the original picture. Further, this relationship should follow a u-shape with stronger contrast manipulation being experienced as more disfluent. Manipulating contrast in two directions will further allow to explore whether more than one optimal level of disfluency for memory encoding can be identified. This should be indicated by greater sensitivity to the memory signal for disfluency for both, positive- and negative contrast manipulations. A surprise recognition memory paradigm will be used to investigate memory performance as both disfluency-memory- and cognitive-control memory effects have already successfully been found using it (Krebs et al., 2013; Rosner et al., 2015).

Third, to account for the potential impact of fluency on response style, in the memory paradigms signal detection theory will be used for analysis of memory performance. It is hypothesized that a greater sensitivity to the memory signal (*d'*) can be observed in disfluent trials, compared to fluent ones, while a greater bias to respond old (*c*) can be observed for fluent trials, compared to disfluent trials. Last, to increase understanding of possible underlying cognitive mechanisms, individual ability in cognitive control will be related to performance on the disfluency-memory paradigm (De Galan et al., 2014; Krebs et al., 2013). It is hypothesized that a positive correlation between individual ability in cognitive control, as indicated by performance measures of RT, accuracy, as well as conflict adaptation, and performance on the (dis)fluency tasks, as indicated by scores of FF, RT, as well as *d'*, will be found.

Methods

Ethics Statement

All experiments described in this thesis were conducted according to principles laid out in the declaration of Helsinki (World Medical Association, 2013). The main experiment was approved by the ethics committee of the University of Vienna, Austria, (Reference Number: 00345) who reviewed the study protocol, consent form and participant information. Although, in the surprise recognition memory task participants were not informed in the beginning of the experiment that they would perform such a task in the course of the experiment, participants were debriefed at the end of the experiment. All participants were also made aware that they could withdraw their consent for the experiment, before, during, and at the end of the experiment.

Prestudy

In a first step a short online study was run to validate the hypothesis of positive and negative contrast impacting perceived fluency, as well as to test the stimulus set. Primary aim of the prestudy was to explore whether positive and negative contrast both exhibit a similar fluency response in participants, and whether a U-shaped relationship could be established. This should be indicated by higher ratings of FF for more disfluent stimuli.

Participants. Forty-three participants were recruited via snowball system from friends and family of the main author. Participants were sent a link to an online-survey created using SosciSurvey (Leiner, 2014).

Materials, Design, & Procedure. Participants were presented 20 manmade and 20 natural photographs of landscapes in randomized order for 3 seconds. Of each stimulus 5 different versions were created, and one version was randomly selected for presentation (-90, -45, 0, 45, 90, contrast as manipulated in GIMP (The GIMP Team, 2018), Figure 3). After stimulus presentation participants were asked to indicate felt fluency (FF) on a 7-point Likert scale ("how easy was the perception of the stimulus?", from 1 = *very easy* to 7 = *very hard* ; Forster et al., 2013).

Figure 3. Contrast manipulation of a photograph depicting a natural scene.

Results Prestudy

Mean FF ratings were computed for each participant and contrast condition. A repeated measures ANOVA was used to test for the effect of visual contrast on FF. Mauchley's test indicated that the assumption of sphericity had been violated $\chi^2(9) = 76.87$, $p < .001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .60$). Results revealed a significant effect $F(2.35, 98.87) = 39.56$, $p < .001$, $\eta_p^2 = .49$. Tests of within subject contrasts further revealed a quadratic relationship $F(1, 42) = 66.13$, $p < .001$ (see also Figure 4). Four paired sample t-tests were used for comparisons between the adjacent contrast conditions (see Table 1 for an overview of means and standard deviations). There was a significant difference between the -90 and -45 contrast conditions $t(42) = 6.03$, $p < .001$; between the -45 and 0 contrast conditions $t(42) = 5.53$, $p < .001$; between the 0 and 45contrast condition $t(42) = -5.12$, $p < .001$; and between the 45 and 90 contrast condition $t(42) = -7.46$, $p < .001$.

Table 1.

FF means and standard deviations for the 5 contrast manipulations used in the prestudy.

	Visual Contrast				
	-90	-45	0	45	90
FF					
M (*SD*)	3.57 (1.24)	2.68 (1.11)	2.17 (1.13)	2.83 (1.00)	4.03 (1.16)

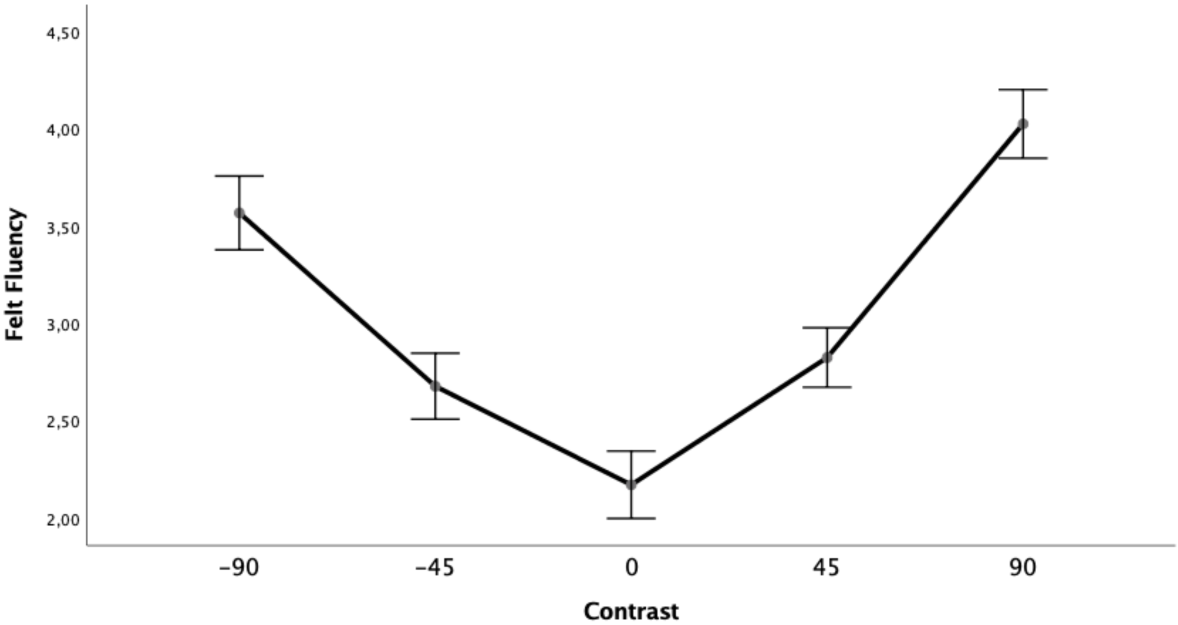

Figure 4. Effect of contrast on FF. Error bars represent standard errors of the mean.

Discussion Prestudy

In line with our hypothesis, the prestudy revealed that positive and negative contrast of a photograph were judged as harder to process than medium contrast, as indicated by increased FF ratings. Further, this relationship followed a u-shape.

Main Experiment

Having established a u-shaped relationship between FF and contrast in the prestudy, the second experiment aimed at testing, whether a similar relationship could be established for disfluency and memory performance, and whether individual differences in a cognitive control task might be correlated to individual performance on the disfluency memory task.

Participants. Eighty undergraduate psychology students (62 female) participated in the experiment in exchange for course credit. Participants age ranged from 18 to 32 (*M* = 21.33, *SD* = 2.99).

Materials, Design and Procedure

Stimuli. Stimuli used in the fluency and disfluency-memory paradigm were 56 photographs of natural- and 56 photographs of manmade landscapes, resulting in a stimulus set of 112 photographs. Photographs were varied in contrast, so that for each stimulus seven different versions were created (-90, -60, -30, 0, 30, 60, and 90, contrast as manipulated in GIMP (The GIMP Team, 2018), Figure 5). At the beginning of an experimental session for each participant one of the seven versions was randomly selected for presentation throughout the experiment.

Figure 5. Fluency manipulation for the main study. For each participant one of the seven versions for each stimulus was selected at the beginning of the experiment for presentation, while the contrast manipulation was held constant throughout the experiment.

Procedure

All participants went through the same procedure. After filling out an informed consent, participants engaged in a fluency/encoding task. Afterwards they did a filler-task for 5 minutes. Then they engaged in a surprise recognition task, followed by a cognitive-control task. Last, demographic information (age, gender, perceived purpose of experiment) was assessed. The experiment was be programmed and run in OpenSesame 3.2.6 (Mathôt, Schreij, & Theeuwes, 2012).

Encoding/Fluency Task. First, in a fluency task, which also served as an encoding phase for the later surprise recognition task, participants were presented with 84 of the 112 photographs. Of the 84 photographs presented during the encoding phase 42 had a natural- and 42 a manmade content. Contrast manipulations were distributed evenly, so that of the 7 contrast manipulations, 6 photographs for each manipulation for each category (manmade, natural) were included in the stimulus set.

Participants went through the set of 84 photographs twice. In both runs the same three stimuli (not from the stimulus set) were used for familiarization trials. In a first, randomized run through the stimuli, participants were asked to indicate as fast as possible whether the scene depicted in the stimulus was natural or manmade. Independent of participants response time stimuli were shown for 2 seconds each to not introduce a possible fluency bias due to longer presentation times. In case participants failed to provide an answer in the 2 seconds a feedback message was presented to participants (*too slo*w). Following, in a second randomized run through the 86 stimuli participants were asked to indicate how easy was the perception of the stimulus was on a 7-point Likert scale ranging (FF, from 1 = *very easy* to 7 = *very hard*; Forster et al., 2013). Stimuli were displayed for 3 seconds each. Ratings were given after stimulus presentation in an additional screen.

Filler task

Next participants engaged in a filler task to draw attention away from the stimuli presented in the fluency task. Here, participants were asked to categorize numbers ranging from 0 to 9 according to rules as fast as possible. Numbers were presented either in red or blue font. For red numbers participants had to indicate whether the number was larger or smaller than 5. For blue numbers participants had to indicate whether the number was even or odd. First, participants were instructed to take some time to memorize the rules. Then, participants went through 9 trials in which stimuli only appeared in blue. Next, participants were made aware that from now on numbers will appear in both blue and red. Then participants went through 96 trials. Throughout the task, trials appeared for a maximum of 1500ms or until the participants made a response. After each trial a message appeared on the screen for 300ms that gave feedback to the participant (*correct*, *wrong*, or *too slow*).

Surprise recognition task

Next participants engaged in a surprise recognition task. Here, 56 randomly drawn images from the fluency/encoding task, as well as the remaining 28 previously unseen stimuli were presented for a total of 84 stimuli. As in the encoding task stimuli were selected so that half had manmade and half had natural content. Further, for each contrast manipulation the same number of pictures were presented. The proportion of content and contrast manipulation was the same for new and old stimuli. Participants were asked to indicate whether they had seen the presented stimuli before using a remember/know response mapping (1 = *definitely old*, 2 = *probably old*, 3 = *probably new*, 4 = *definitely new*; Wixted, 2009). First, participants did 3 familiarization trials with photographs not used for the fluency/encoding task. Afterwards the main task started.

Cognitive control task

Last, participants engaged in a Stroop task. Here participants were presented with color words (red, blue, green) either in a congruent (e.g., blue written in blue) or incongruent (e.g., blue written in red) font color. Participants were asked to respond as fast as possible to the color, while ignoring the word. After 9 familiarization trials participants engaged in two blocks with 72 trials each. Inter trial intervals were varied randomly between 750 and 1750ms in steps of 100ms. Stimuli were presented for 1500ms or until the participant responded. In case the participants did not respond in the 1500ms time window a feedback message was presented. Half of the trials were incongruent, half congruent. Each font color and word appeared with the same frequency.

Results

Effect of Contrast on Felt Fluency

First, as a manipulation check the effect of contrast on FF ratings was explored. Mean FF ratings were computed for each contrast condition. A one-way repeated measures ANOVA was conducted to compare the effect of contrast on FF ratings. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi 2(20) = 256.76$, $p < .001$. Therefore, a Greenhouse-Geisser correction was used ($\varepsilon = .49$). There was a significant effect of contrast on FF, $F(2.92, 89.41) = 107.43$, $p < .001$, $\eta_p^2 = .58$ (Figure 6). Tests of within subject contrasts revealed a quadratic relationship $F(1, 79) = 221.87$, $p < .001$. Planned paired sample t-tests were used to make comparisons between conditions. Alpha-levels were not corrected as the hypothesis specifies a difference between contrast levels. A significant difference between the -90 ($M = 3.66$, $SD = .141$) and -60 ($M = 2.85$, $SD = .11$) contrast conditions, $t(79) = 10.43$, $p < .001$, between the -60 ($M = 2.85$, $SD = .11$) and -30 ($M = 2.34$, $SD = .80$) contrast conditions, $t(79) = 7.75$, $p < .001$, between the 0 ($M = 2.24$, $SD = .84$) and 30 ($M = 2.38$, $SD = .92$) contrast conditions, $t(79) = -2.71$, $p = .008$, between the 30 ($M = 2.38$, $SD = .92$) and 60 ($M = 3.13$, $SD = 1.08$) contrast conditions, $t(79) = -9.42$, $p < .001$ and between the 60 ($M = 3.13$, $SD = 1.08$) and 90 ($M = 4.18$, $SD = 1.31$) contrast conditions, $t(79) = -12.84$, $p < .001$ was found.

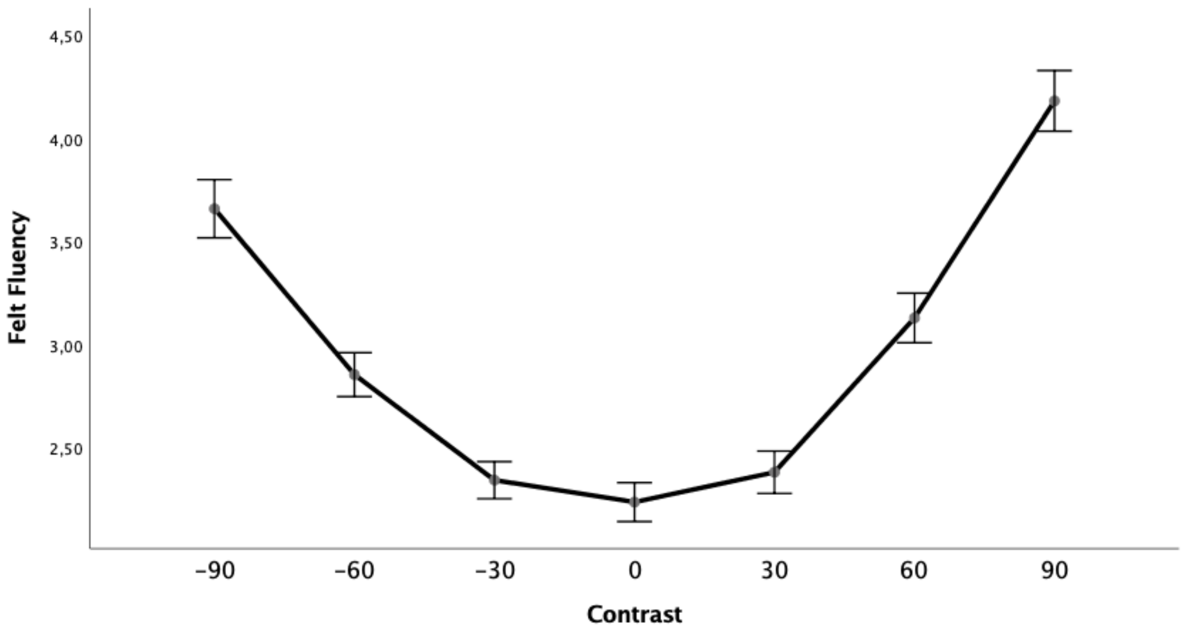

Figure 6. Effect of contrast on FF. Error bars represent standard errors of the mean.

Effect of Contrast on Reaction Time

As a second manipulation check the effect of contrast on reaction time (RT) during the manmade/natural categorization task was explored. Trials in which participants failed to respond in the two second time window were excluded from the analysis. Mean RT for each contrast condition were computed. A second repeated measures ANOVA was conducted to compare the effect of contrast on RT during the manmade/natural categorization task. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi 2(20) = 52.21$, $p < .001$. Therefore, a Greenhouse-Geisser correction was used ($\varepsilon = .84$), which revealed a significant effect of contrast, $F(5.03, 397.16) = 6.11$, $p < .001$, $\eta_p^2 = .072$ (Figure 7). Tests of within subject contrasts revealed a quadratic relationship $F(1, 79) = 26.98$, $p < .001$. Planned paired sample t-tests were used to make comparisons between conditions. Alpha-levels were not corrected as the hypothesis clearly specifies a difference between contrast levels. A significant difference between -90 ($M = 734.41$, $SD = 152.70$) and -60 ($M = 713.52$, $SD = 150.21$) contrast conditions, $t(79) = 2.17$, $p = .033$, and a significant difference between the 30 ($M = 681.80$, $SD = 131.83$) and 60 ($M = 707.56$, $SD = 153.11$) contrast conditions, $t(79) = -2.95$, $p = .004$ were revealed.

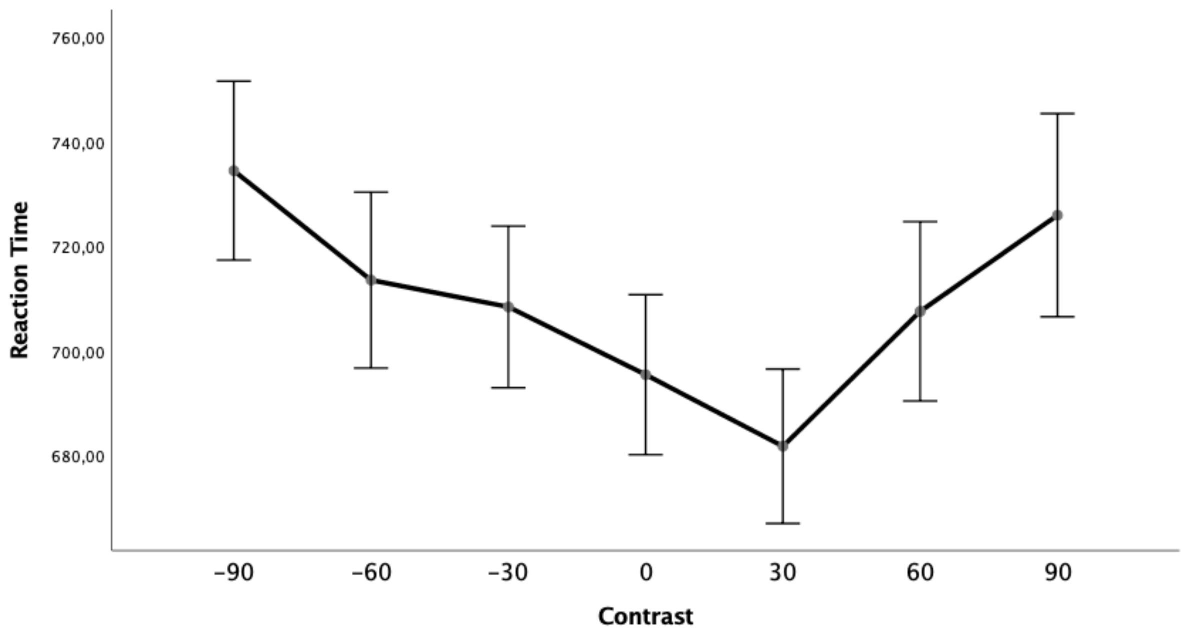

Figure 7. Effect of contrast on RT in the natural/manmade categorization task. Error bars represent standard errors of the mean.

Computing Sensitivity to the Memory Signal (*d'*) and Response Bias (*c*)

To investigate performance in the surprise recognition task sensitivity to the memory signal (*d'*) and response bias (c) were computed (Stanislaw & Todorov, 1999). For each participant number of hits (correct old classifications) and false alarms (incorrect old classifications) were computed. Only *definitely old* responses were counted as correct recognition. Then, *d'* was computed for each contrast manipulation as the difference between z-transformed hits and false-alarms, such that a *d'* of 0 indicates inability to distinguish the memory signal from noise and a higher *d'* indicates that the signal can more easily be detected. Similarly, for each contrast manipulation *c* was computed as sum of z-transformed hits and false alarms multiplied by -0.5, such that $c > 0$ indicates a bias to respond old, and $c < 0$ indicates a bias to respond new. Signal detection theory cannot be applied to cases in which hit or false alarm rates of 0 or 1 exist. Therefore, these cases were transformed. Hit and false alarm rates of 0 were replaced with $.5/n$, and hits and false alarm rates of 1 with $(n – .5)/n$, where n is the number of signal or noise trials (Stanislaw & Todorov, 1999).

Effect of Contrast on Sensitivity to the Memory Signal (*d'*)

Next, the effect of contrast on performance during the surprise recognition task was targeted to investigate whether contrast had an impact on recognition rate. A repeated measures ANOVA was conducted to compare the effect of contrast on *d'*. A significant effect of contrast was revealed $F(6, 74) = 5.98$, $p < .001$, $\eta_p^2 = .07$ (Figure 8). Tests of within subject contrasts further revealed a quadratic relationship $F(1, 79) = 15.30$, $p < .001$. Planned paired sample t-tests were used to make comparisons between conditions. Alpha-levels were not corrected as the hypothesis clearly specifies a difference between contrast levels. A significant difference between -90 ($M = .84$, $SD = .51$) and -60 ($M = 1.05$, $SD = .45$) conditions, $t(79) = -3.71$, $p < .001$, was revealed while no significant difference was found between all other conditions.

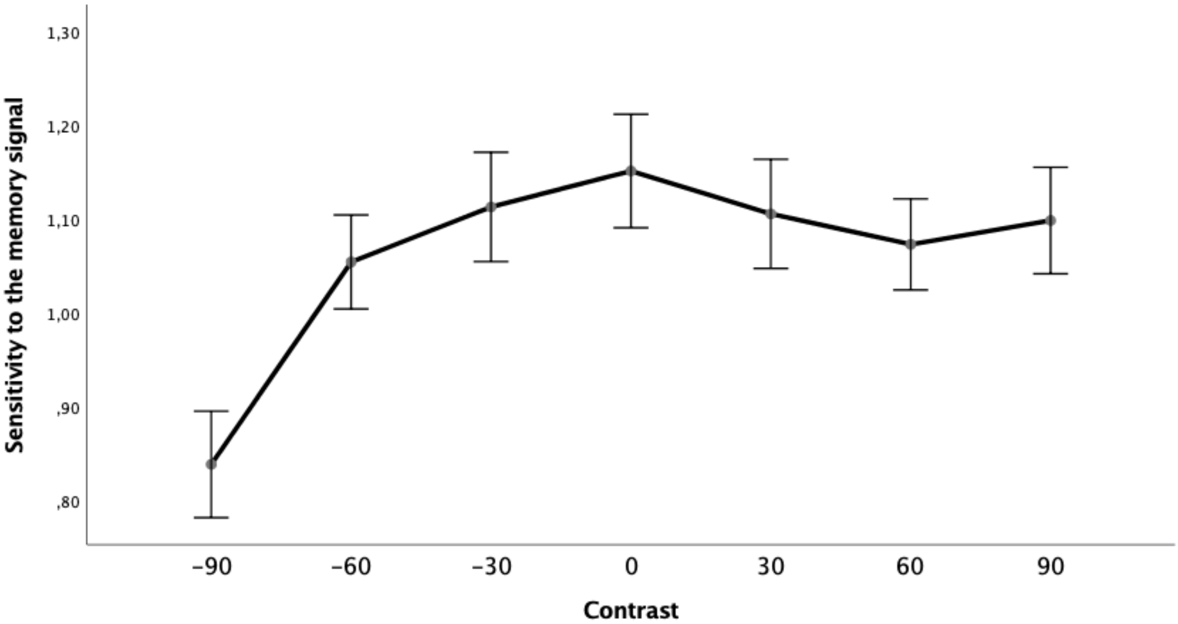

Figure 8. Effect of contrast on sensitivity to the memory signal. Error bars represent standard errors of the mean.

Effect of contrast on response bias (*c*)

In memory paradigms fluency has been found to impact the response bias *c*, the bias to respond old, even though an item is new. Therefore, more fluent contrast conditions should exhibit a stronger response bias *c*. A repeated measures ANOVA was conducted to compare the effect of contrast on *c*. A significant effect of contrast was revealed $F(6, 74) = 2.30$, $p = .043$, $\eta_p^2 = .16$ (Figure 9). Tests of within subject contrasts revealed a linear relationship $F(1, 79) = 7.85$, $p = .006$. Planned paired sample t-tests were used to make comparisons between conditions. A significant difference between the -90 ($M = .43$, $SD = .38$) and -60 ($M = .35$, $SD = .36$) conditions, $t(79) = 2.22$, $p = .029$ was revealed, while no significant difference was found between all other conditions.

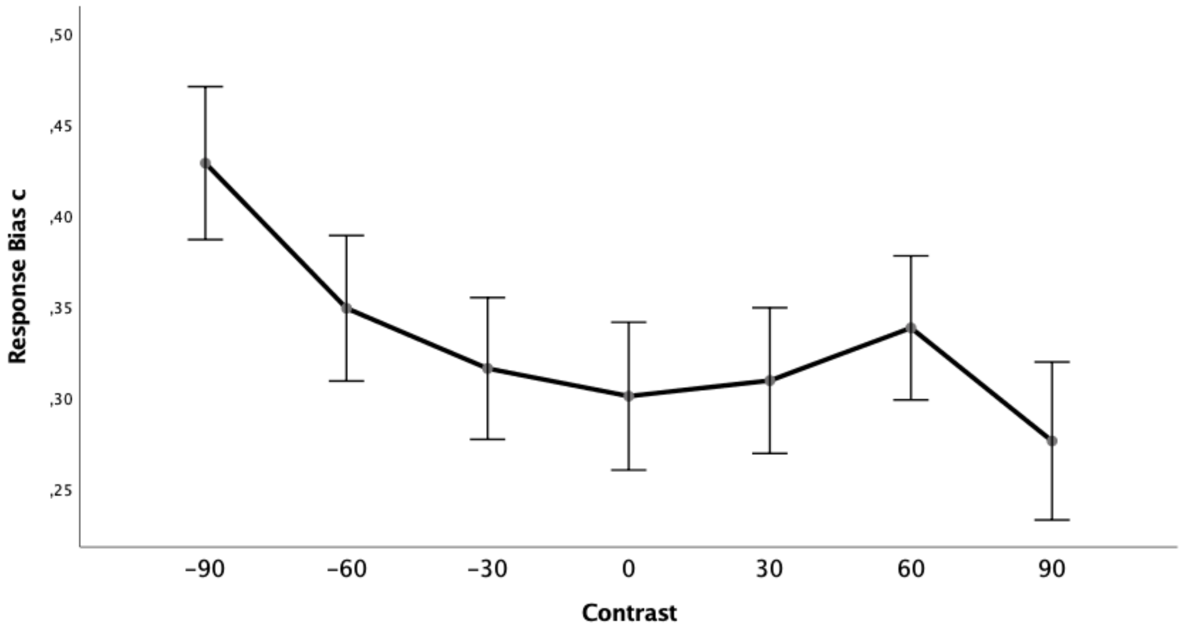

Figure 9. Effect of visual contrast on response bias *c*. Error bars represent standard errors of the mean.

Effect of other Fluency indicators (FF and RT) on Memory Performance

The present experiment allowed for another approach to investigate memory performance: It is possible that contrast itself is not the best predictor of (dis)fluency, but that FF or RT during the manmade/natural categorization task capture the concept of (dis)fluency more accurate. Therefore, two logistic regressions were carried out to establish whether FF ratings, as well as RT during the manmade/natural categorization task, impact the likelihood to obtain a correct response on the respective trial in the memory task (hit vs miss). For RT, trials in which participants did not give a response in the two second time window were excluded. A logistic regression of FF ratings on memory performance was not significant, $\chi 2(1) = 1.69$, $p = .19$. A logistic regression of RT on memory performance was not significant $\chi 2(1) = .27$, $p = .60$.

Performance in the Stroop Task

For the Stroop task mean RT and accuracy measures were computed for further analysis. For the RT measure error and post-error trials were excluded from analysis. Two paired sample t-tests for RT in correct trials and accuracy rates were computed for incongruent vs congruent trials respectively. Participants were faster in congruent trials (*M* = 600.79, *SD* = 82.91) than in incongruent trials (*M* = 697.95, *SD* = 119.98), $t(79) = -14.94$, $p < .001$. Further, participants were more accurate in congruent trials (*M* = .96, *SD* = .11) compared to incongruent trials (*M* = .90, *SD* = .12), $t(79) = 7.22$, $p < .001$.

Next, to investigate conflict adaptation, RT and percentage accuracy were analyzed in two 2 x 2 previous trial type (congruent vs incongruent) x current trial type (congruent vs incongruent) repeated measures ANOVAs. Descriptive statistics can be found in Table 2. For RT a main effect of current trial type ($F(1, 79) = 205.46$, $p < .001$, $\eta_p^2 = .73$), but no main effect for previous trial ($F(1, 79) = 0.20$, $p = .66$) or interaction between previous and current trial ($F(1, 79) = 2.0$, $p = .16$) were found. For accuracy a main effect of current trial type was found, $F(1, 79) = 225.60$, $p < .001$, $\eta_p^2 = .74$, but no main effect of previous trial ($F(1, 79) = 1.95$, $p = .17$) or interaction between previous and current trial ($F(1, 79) = 0.05$, $p = .82$).

Table 2.

Mean RT for correct trials and percentage correct trials for each trial type. Trial refers to the previous followed by the current trial type (CC = congruent – congruent, CI = congruent – incongruent, IC = incongruent – congruent, II = incongruent – incongruent).

Trial type	RT (ms)	SD	Accuracy (%)	SD
CC	601.87	89.43	95.43	11.36
CI	598.33	81.50	95.97	11.27
IC	695.09	122.04	90.08	13.10
II	701.71	123.22	90.81	12.88

Correlating Individual Ability in Cognitive Control and Fluency

Next, for correlational analysis four scores were computed as indicators of individual ability in cognitive control (see De Galan et al., 2014 for a similar approach): The size of the Stroop effect in RT (RT in incongruent trials – RT in congruent trials), the size of the Stroop effect in accuracy (accuracy in congruent trials – accuracy in incongruent trials), the size of conflict adaptation in RT ((CI (congruent trial following incongruent trial) – CC (congruent trial following congruent trial) – (II (incongruent trial following incongruent trial) – IC (incongruent trial following congruent trial)), and last the size of conflict adaptation in accuracy ((CI – CC) – (II – IC)).

Further, three scores were computed as indicators of individual performance in the fluency paradigms by comparing the -90 and the 0-contrast condition for FF, RT and *d'*: the size of the disfluency effect in the surprise recognition memory paradigm ($d'_{minus90}$ – d'_0), the size of the fluency effect for FF (FF_{-90} – FF_0) and the size of the fluency effect for RT during the natural/manmade categorization task (RT_{-90} – RT_0). Descriptive statistics for individual ability in cognitive control and fluency can be found in Table 3. In a next step, correlations between measure of individual ability in cognitive control and fluency were computed. Results can be found in Table 4.

Table 3.

Means and standard deviation for variables measuring individual ability in cognitive control and fluency.

Variable	Mean	SD
Stroop RT	97.16	57.81
Stroop accuracy	.052	.065
Conflict adaptation RT	-10.17	63.96
Conflict adaptation accuracy	-.002	.075
Disfluency	.313	.617
FF	1.42	1.20
Fluency - RT	38.95	92.03

Table 4.

Correlations between individual ability in cognitive control and fluency.

	Stroop RT	Stroop Accuracy	Conflict Adaptation RT	Conflict Adaptation Accuracy
Disfluency	.01	.054	-.135	-1.28
FF	-.022	-.01	-.194	-.011
Fluency - RT	-.074	-.116	.046	-.209

* $p < .05$

Discussion

The experiments reported here investigated the impact of continuous visual contrast variation on fluency and recognition memory. A prestudy found that positive and negative contrast variations of visual stimuli have a similar effect on FF ratings, namely that stronger contrast is associated with greater difficulty in perceiving the stimuli, and that this relationship followed a u-shape. The main experiment replicated the effect of visual contrast on FF in a larger sample using a greater number of contrast variations and extended the findings towards a RT measure in a natural/manmade categorization task, indicating that visual contrast manipulations impact perceived fluency in both RT and FF ratings. However, in contrast to our predictions, no positive effect of disfluency on surprise recognition memory was found. Compared to all other 6 contrast manipulations reduced sensitivity to the memory signal was found in the lowest negative contrast manipulation, while the other 6 contrast manipulation led to a similar level of sensitivity to the memory signal. Last, individual ability of cognitive control was measured by performance on a Stroop task and correlations with individual performances on the surprise recognition memory paradigm, as well as FF ratings during encoding and RT during the manmade/natural categorization task were computed. However, no significant relationship was found, indicating that no direct connection between individual performance in cognitive control and fluency tasks could be observed.

The effect of disfluency on surprise recognition memory

Both experiments described here present evidence that visual contrast influences processing fluency. A prestudy found an effect of visual contrast on FF ratings, and the main experiment replicated and extended these findings towards a RT measure. The relationship between fluency and visual contrast in the experiments followed a u-shape: both negative and positive visual contrast led to more disfluent ratings and longer RT. These findings are in line with theoretical accounts that propose an optimal level of processing for fluency (Berlyne, 1971; Reber, 2012). However, contrary to theoretical accounts (Bjork & Bjork, 2011; Oppenheimer & Alter, 2014) and previous experimental findings (e.g., Besken & Mulligan, 2013; Diemand-Yauman et al., 2010), no positive effect of disfluency on surprise recognition memory was found. This finding was strengthened by two logistic regressions using FF or RT during the manmade/natural categorization task to predict later hits or misses that did not find any significant effect.

Still, in the present experiment, the strongest negative manipulation of visual contrast, compared to all other contrast variations, was associated with reduced sensitivity to the memory signal. This finding raises a number of important questions: First, the visual contrast manipulation used in the experiment described here showed a strong effect on processing fluency (FF and RT). Not finding a memory effect therefore raises the question whether a disfluency memory effect and classical fluency accounts measure the same underlying construct (see Figure 10 for a comparison). In other words, just experiencing a stimulus as (dis)fluent might not necessarily entail an impact on encoding and retrieval into memory. As for the quadratic relationship found in the effect of contrast on sensitivity to the memory signal it can be speculated that this was driven by the strong negative effect of the lowest contrast manipulation, while no difference between the other six contrast manipulations was observed. The quadratic relationship does thus not indicate a u-shaped relationship, but probably a change in slope (see Simonsohn, 2018). Future research might aim at further disentangling conditions in which disfluency impacts memory performance and ones in which it does not. However, it has to be stressed that this finding strengthens theoretical accounts claiming that no effect of disfluency on surprise recognition memory exists (Kühl & Eitel, 2016; Xie et al., 2018) and previously published results might just be false positives.

Second, although no positive effect of disfluency on surprise recognition memory was found, the reduced memory for the strongest negative contrast manipulation confirms part of the desired difficulties theoretical account: a strong level of disfluency leads to impaired memory recall (Bjork & Bjork, 2011; Rosner et al., 2015). Interestingly, in the experiments reported here this effect was only present for negative contrast, but not for positive contrast. At the same time both FF ratings and RT indicate that positive and negative contrast had a similar effect on fluency. Following, it is possible that positive and negative contrast are processed differently with regard to surprise recognition memory, but not with regard to fluency itself, and thus a difference between the manipulations was observed.

Also, no predicted effect of contrast on response bias *c* was found as contrast manipulations that were rated as more fluent were not associated with a tendency to respond old. In contrast, a stronger bias to respond old was found for the -90-contrast manipulation, compared to all other contrast manipulations. This means that participants were more likely to classify a picture as previously seen, independent if it was actually old or a previously unseen distractor) for the -90-condition. This finding can be explained in the context of a reduced sensitivity to the memory signal for the -90-contrast condition. As participants could not as readily use their memory signal to classify the -90-conditions they might have turned towards a different response style.

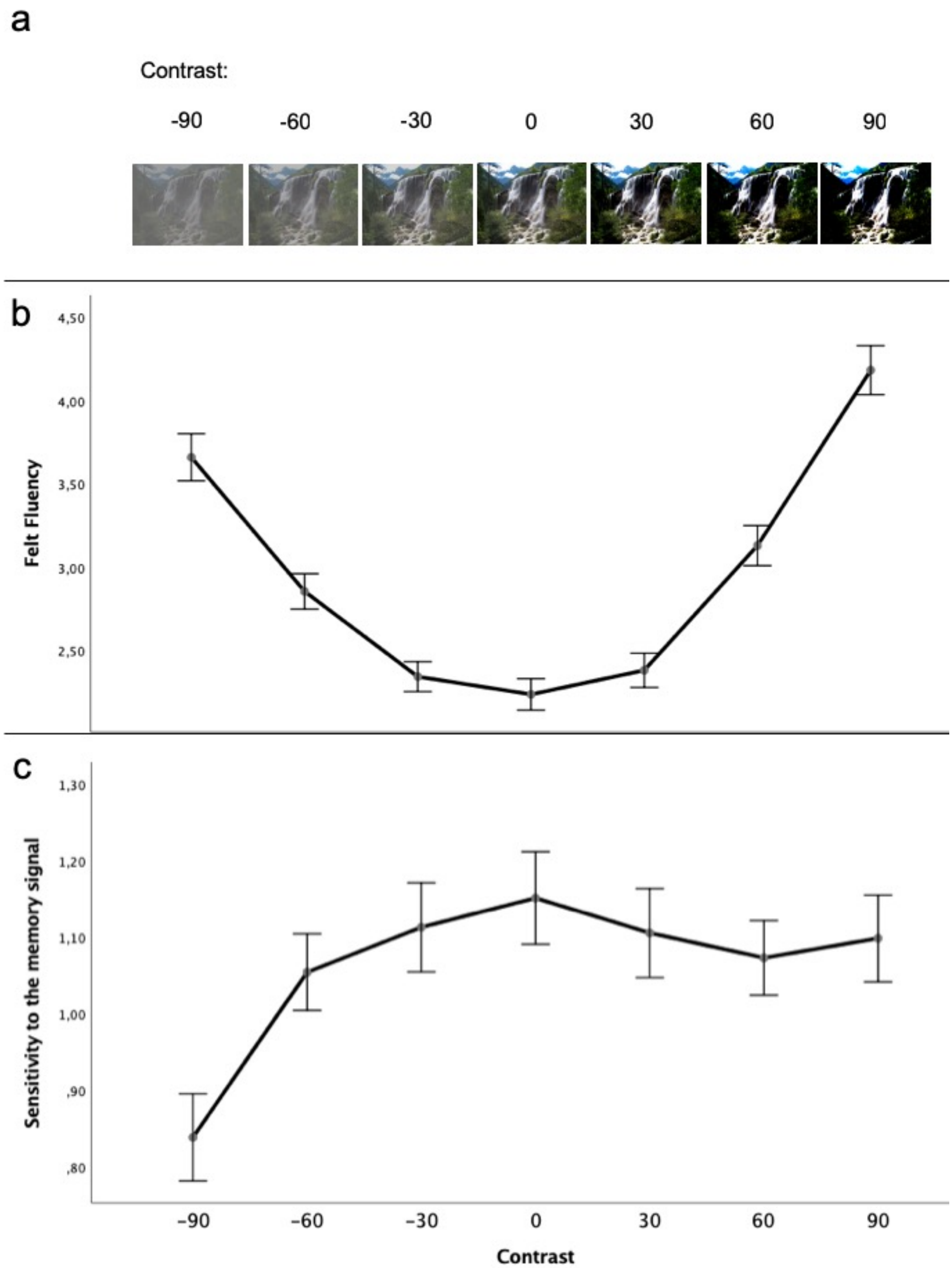

Figure 10. Comparison of a) contrast manipulation used in the main experiment, b) effect of contrast on FF, and c) effect of contrast on sensitivity to the memory signal *d'*.

The relationship between individual ability of cognitive control and disfluency

Another aim of the thesis was to relate a disfluency memory effect to individual ability in cognitive control operationalized by performance on a Stroop task. It was hypothesized that a positive correlation between performance on the Stroop task and performance on the (dis-)fluency tasks can be established. However, no significant correlation was observed. This could indicate that no relationship between individual ability in cognitive control and (dis)fluency exists.

Still, alternative explanations for a lack of significant correlations have to be discussed: first, one of the manipulation checks failed as no effect of conflict adaptation was found, indicated by no significant interaction between current and previous trial in the Stroop task. Previous research relating individual ability in cognitive control with constructs other than fluency has found correlations for conflict adaptation but not for other measures (De Galan et al., 2014). Not finding an effect of conflict adaptation might have thus hindered the discovery of a correlation. As for the lack of a significant interaction the low number of trials in the Stroop task (144) or fatigue, as the Stroop task was done last in the experiment, are potential explanations.

Second, the null-result for a correlation between individual performance in cognitive control and (dis)fluency tasks might be traceable to not finding an impact of disfluency on memory performance in general. In other words, finding a correlation between individual performance in cognitive control and disfluency would be surprising if no effect of disfluency was found.

Disfluency and Congruency Sequence Effects

Another alternative explanation regarding not finding a positive effect of disfluency on recognition memory, as well as no correlation with individual ability in cognitive control, needs to be discussed here. The present thesis assumed a connection between cognitive control mechanisms and (dis)fluency-memory performance due to the fact that both circle around (negative) affective evaluation (Dreisbach & Fischer, 2015): A disfluent task (compared to a fluent one) can be assumed to exhibit (negative) affective evaluation (Topolinski & Strack, 2015). Similarly, also an incongruent Stroop trial might trigger (negative) affect (Braem et al., 2016).

However, it could also be possible that an underlying mechanism that is involved in both disfluency-memory- and cognitive-control-memory effects does not build on affective evaluation, but on conflict adaptation. Conflict adaptation indices are usually computed in tasks which contrast two conditions with each other (e.g., congruent vs incongruent, fluent vs. disfluent) and builds on the size of the difference between the two conditions.

However, instead of a dichotomous contrast (fluent vs disfluent) the present experiment used 7 different contrast variations. If a disfluency-memory effect does not arise due to affective evaluation, but because of conflict adaptation as response to a change between two stimuli (as is e.g., in the switch from an incongruent to a congruent Stroop trial), then the present experiment was simply not set up to discover a disfluency-memory effect. Future research should aim at further disentangling the relationship between affective evaluation, conflict adaptation, and the impact of both on memory performance.

Implications

The experiments described here did not find evidence for a positive effect of visual disfluency on recognition memory and no correlation of individual ability of cognitive control and (dis)fluency. A potential effect of disfluency on memory is often discussed in the realm of educational settings: some accounts argue that making educational material harder to process should result in better encoding. Though, the implications from the experiments presented here would advise otherwise: making visual stimuli harder to process might, if at all, have a negative effect on recognition memory.

Limitations

Some limitations and further alternative explanations concerning the results of the experiments described here need to be discussed as well. Most studies investigating the effect of disfluency on recognition memory used word stimuli, while the experiments described here utilized visual stimuli. An alternative explanation for the absence of a positive effect of disfluency on recognition memory might thus stem from the use of differing stimuli classes – maybe word- and picture stimuli are impacted differently by (dis)fluency manipulations.

Also, during the surprise recognition paradigm the fluency manipulation was still present. That is, pictures were presented with the same contrast as in the fluency/encoding task which could have impacted responses in the memory task. It has been shown that fluency in recognition paradigms leads to a familiarity based response style, that is more false alarms during fluent trials (Yonelinas, 2002). In principal, the use of sensitivity to the memory signal (d') would control for this. However, only 28 distractor trials (4 per contrast group) were used in the memory task, which resulted in low numbers of false alarms reported that could have impacted the accuracy of the variable (Stanislaw & Todorov, 1999).

Further, it is also possible that although the experiment had a sufficient sample size to discover a traditional fluency effect, power was not sufficient to discover a much smaller memory effect. Following, to be certain that not finding a disfluency memory effect is not related to power issues, future research might aim for high-powered replication studies of established effects.

Conclusion

The present thesis aimed at investigating the impact of visual (dis-)fluency on surprise recognition memory. Visual contrast influenced traditional measures of fluency. However, no positive impact of disfluency on surprise recognition memory was established in the present study. This supports the view that disfluency does not have an impact on memory. Still, strong negative contrast was found to negatively impact surprise recognition memory, thus strengthening part of a desirable difficulties approach that claims that increasing disfluency beyond a certain point is followed by reduced recall abilities. Still, it remains unclear why no similar effect for strong positive contrast was found. Future research should aim at further disentangling this relationship.

References

Alter, A. L. (2013). The Benefits of Cognitive Disfluency. *Current Directions in Psychological Science*, *22*(6), 437–442. https://doi.org/10.1177/0963721413498894

Alter, A. L., & Oppenheimer, D. M. (2009). Uniting the Tribes of Fluency to Form a Metacognitive Nation. *Personality and Social Psychology Review*, *13*(3), 219–235. https://doi.org/10.1177/1088868309341564

Alter, A. L., Oppenheimer, D. M., Epley, N., & Eyre, R. N. (2007). Overcoming Intuition: Metacognitive Difficulty Activates Analytic Reasoning. *Journal of Experimental Psychology: General*, *136*(4), 569–576. https://doi.org/10.1037/0096-3445.136.4.569

Berlyne, D. E. (1971). *Aesthetics and Psychobiology*. New York: Appleton-Century-Crofts. https://doi.org/10.2307/1179240

Besken, M., & Mulligan, N. W. (2013). Easily perceived, easily remembered? Perceptual interference produces a double dissociation between metamemory and memory performance. *Memory & Cognition*, *41*(6), 897–903. https://doi.org/10.3758/s13421-013-0307-8

Bjork, E. L., & Bjork, R. (2011). Making Things Hard on Yourself, But in a Good Way: Creating Desirable Difficulties to Enhance Learning. In M. A. Gernsbacher, R. W. Pew, L. M. Hough, & J. R. Pomerant (Eds.), *Psychology and the real world: Essays illustrating fundamental contributions to society* (Vol. 2, pp. 59–68). New York, NY.

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. P. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 185–205). Cambridge, MA: MIT Press.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, *108*(3), 624–652. https://doi.org/http://dx.doi.org/10.1037/0033-295X.108.3.624

Braem, S., King, J. A., Korb, F. M., Krebs, R. M., Notebaert, W., & Egner, T. (2016). The Role of Anterior Cingulate Cortex in the Affective Evaluation of Conflict, *29*(1), 137–149. https://doi.org/http://dx.doi.org/10.1162/jocn_a_01023

Cohen, J. D. (2017). The basics of cognitive control: Core constructs and current considerations. In T. Egner (Ed.), *The Wiley Handbook of Cognitive Control* (pp. 3–28). Wiley-Blackwell.

https://doi.org/https://doi.org/10.1002/9781118920497.ch1

De Galan, M. D., Sellaro, R., Colzato, L. S., & Hommel, B. (2014). Conflict adaptation is predicted by the cognitive, but not the affective alexithymia dimension. *Frontiers in Psychology*, *5*(JUL), 1–7. https://doi.org/10.3389/fpsyg.2014.00768

Desender, K., Van Opstal, F., & Van den Bussche, E. (2014). Feeling the Conflict. *Psychological Science*. https://doi.org/10.1177/0956797613511468

Dew, I. T. Z., & Cabeza, R. (2013). A Broader View of Perirhinal Function: From Recognition Memory to Fluency-Based Decisions. *Journal of Neuroscience*, *33*(36), 14466–14474. https://doi.org/10.1523/JNEUROSCI.1413-13.2013

Diemand-Yauman, C., Oppenheimer, D. M., & Vaughan, C. (2011). Permalink Fortune Favors the Bold (and the Italicized): Effects of Disfluency on Educational Outcomes. *Cognition*, *118*(1), 111–115. https://doi.org/https://doi.org/10.1016/j.cognition.2010.09.012

Dreisbach, G., & Fischer, R. (2011). If it's hard to read... try harder! Processing fluency as signal for effort adjustments. *Psychological Research*, *75*(5), 376–383. https://doi.org/10.1007/s00426-010-0319-y

Dreisbach, G., & Fischer, R. (2015). Conflicts as Aversive Signals for Control Adaptation. *Current Directions in Psychological Science*, *24*(4), 255–260. https://doi.org/10.1177/0963721415569569

Egner, T. (2017). Conflict Adaptation: Past, present, and future of the congruency sequence effect as an index of cognitive control. In T. Egner (Ed.), *Wiley Handbook of Cognitive Control* (pp. 64–78). Wiley-Blackwell. https://doi.org/https://doi.org/10.1002/9781118920497.ch4

Etkin, A., Egner, T., & Kalisch, R. (2010). Emotional processing in anterior cingulate and medial prefrontal cortex. *Trends in Cognitive Sciences*, *15*, 85–93. https://doi.org/10.1016/j.tics.2010.11.004

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*(2), 280–289. https://doi.org/10.1037/a0030115

Kahneman, D. (2012). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.

Koriat, A., & Ma'ayan, H. (2005). The effects of encoding fluency and retrieval fluency on judgments of learning. *Journal of Memory and Language*, *52*(4), 478–492. https://doi.org/10.1016/j.jml.2005.01.001

Krebs, R. M., Boehler, C. N., De Belder, M., & Egner, T. (2013). Neural conflict-control mechanisms improve memory for target stimuli. *Cerebral Cortex*, *25*(3), 833–843. https://doi.org/10.1093/cercor/bht283

Kühl, T., & Eitel, A. (2016). Effects of disfluency on cognitive and metacognitive processes and outcomes. *Metacognition and Learning*, *11*(1), 1–13. https://doi.org/10.1007/s11409-016-9154-x

Leiner, D. (2014). Sosci Survey. Retrieved from https://www.soscisurvey.de/

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods*, *44*(2), 314–324. https://doi.org/10.3758/s13428-011-0168-7

New York Times. (2011). Come On, I Thought I Knew That! Retrieved April 17, 2019, from https://nyti.ms/2Qc2KcI

Open Sciene Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*. https://doi.org/10.1126/science.aac4716

Oppenheimer, D. M., & Alter, A. L. (2014). The search for moderators in disfluency research. *Applied Cognitive Psychology*, *28*(4), 502–504. https://doi.org/10.1002/acp.3023

Reber, R. (2012). Processing Fluency, Aesthetic Pleasure, and Culturally Shared Tasre. In A. P. Shimamura & S. E. Palmer (Eds.), *Aesthetic science: Connecting minds, brains, and experience* (pp. 223–249). New York, NY: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199732142.001.0001

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience? *Personality and Social Psychology Review*, *8*(4), 364–382. https://doi.org/10.1207/s15327957pspr0804_3

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of Perceptual Fluency on Affective Judgments. *Psychological Science*, *9*(1), 45–48. https://doi.org/10.1111/1467-9280.00008

Richter, F. R., & Yeung, N. (2012). Memory and Cognitive Control in Task Switching. *Psychological Science*, *23*(10), 1256–1263. https://doi.org/10.1177/0956797612444613

Rosner, T. M., Davis, H., & Milliken, B. (2015). Perceptual blurring and recognition memory: A desirable difficulty effect revealed. *Acta Psychologica*, *160*, 11–22. https://doi.org/10.1016/j.actpsy.2015.06.006

Schooler, L. J., & Hertwig, R. (2005). How forgetting aids heuristic inference. *Psychological Review*, *112*(3), 610–628. https://doi.org/10.1037/0033-295X.112.3.610

Simonsohn, U. (2018). Two-Lines : A Valid Alternative to the Invalid Testing of U-Shaped Relationships with Quadratic Regressions. *Advances in Methods and Practices in Psychological Science*, *1*(4), 538–555. https://doi.org/https://doi.org/10.1177/2515245918805755

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers*, *31*(1), 137–149. https://doi.org/https://doi.org/10.3758/BF03207704

The GIMP Team. (2018). GIMP. Retrieved from https://www.gimp.org/

The Guardian. (2018). Font of all knowledge? Researchers develop typeface they say can boost memory. Retrieved April 17, 2019, from https://www.theguardian.com/artanddesign/2018/oct/04/font-of-all-knowledge-researchers-develop-typeface-they-say-can-boost-memory

Topolinski, S., & Strack, F. (2015). Corrugator activity confirms immediate negative affect in surprise. *Frontiers in Psychology*, *6*, 1–8. https://doi.org/10.3389/fpsyg.2015.00134

Westerman, D. L., Lanska, M., & Olds, J. M. (2015). The effect of processing fluency on impressions of familiarity and liking. *Journal of Experimental Psychology: Learning Memory and Cognition*. https://doi.org/10.1037/a0038356

Westerman, D. L., Lloyd, M. E., & Miller, J. K. (2002). The attribution of perceptual fluency in recognition memory: The role of expectation. *Journal of Memory and Language*, *47*(4), 607–617. https://doi.org/10.1016/S0749-596X(02)00022-0

Wixted, J. T. (2009). Remember/Know judgments in cognitive neuroscience: An illustration of the underrepresented point of view. *Learning and Memory*, *16*(7), 406–412. https://doi.org/10.1101/lm.1312809

World Medical Association. (2013). *World medical association declaration of Helsinki: ethical principles for medical research involving human subjects*. https://doi.org/10.1001/jama.2013.281053

Xie, H., Zhou, Z., & Liu, Q. (2018). Null Effects of Perceptual Disfluency on Learning Outcomes in a Text-Based Educational Context: a Meta-analysis. *Educational Psychology Review*, *30*(3), 745–771. https://doi.org/10.1007/s10648-018-9442-x

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30

years of research. *Journal of Memory and Language*, *46*(3), 441–517.
https://doi.org/10.1006/jmla.2002.2864

List of Abbreviations

ACC = Anterior cingulate cortex

FF = Felt fluency

RT = Reaction time

Appendix

English Abstract

Recently, researchers have started to explore the impact of disfluency, as opposed to fluency, investigating the consequences of hard to process stimuli. Disfluency has been proposed to increase memory for a stimulus by directing increased attentional resources to it. Most research in this area has been conducted using word stimuli and dichotomous fluency contrasts. Few empirical approaches have investigated underlying cognitive mechanisms of a disfluency-memory effect. Cognitive control processes have been proposed to be a potential underlying mechanism. However, null-findings have cast doubt on the effect in general. The present thesis explored the impact of visual contrast manipulations of simple photographs on performance in fluency- and disfluency-memory paradigms and its relation to individual ability in cognitive control operationalized by a Stroop task. Results showed that although traditional fluency effects were found, no positive impact of disfluency on memory performance in a surprise recognition paradigm could be established. Moreover, the strongest negative contrast manipulation impaired memory performance compared to all other contrast manipulations. No correlation between individual abilities of cognitive control and (dis)fluency were found. The findings question theoretical accounts that propose a positive effect of disfluency on memory performance and suggest that related findings might be false positives. Applying disfluency manipulations as a mean for learning should thus be taken with caution, especially in the case of visual stimuli.

Kurzzusammenfassung

Aktuelle Forschung beschäftigt sich mit dem Einfluss von disfluenten-, im Vergleich zu fluenten, Stimuli, um zu untersuchen, welche Auswirkungen die Schwere der Verarbeitung hat. Einige Studien haben gezeigt, dass disfluente Stimuli bessere Gedächtnisleistung unterstützen, indem Sie zusätzliche Aufmerksamkeitsressourcen aktivieren. Die meisten Studien aus dem Bereich der disfluenten Gedächtniseffekte haben Wort-Stimuli und dichotome Definitionen von fluenten Stimuli benutzt. Weiter haben sich wenige empirische Studien mit möglichen zugrunde liegenden kognitiven Mechanismen befasst. Kürzlich wurde jedoch vorgeschlagen, dass kognitive Kontrolle ein solcher Mechanismus sein könnte. Jedoch ist zu erwähnen, dass fehlgeschlagene Replikationen diesen Effekt im Allgemeinen in Frage gestellt haben. Die vorliegende Masterarbeit hat den Einfluss von visuellen Kontrast-Manipulationen einfacher Photographien auf die Leistung in experimentellen Paradigmen, die fluente Verarbeitung und disfluente-Gedächtnisleistung untersuchen, untersucht. Weiter wurden diese Ergebnisse mit individueller Fähigkeit in kognitiver Kontrolle, operationalisiert durch ein Stroop Paradigma, korreliert. Ergebnisse zeigen, dass obwohl traditionelle Effekte von fluenten Stimuli gefunden werden konnten, kein positiver Effekt von disfluenten Stimuli auf die Gedächtnisleistung feststellbar war. Darüber hinaus hat die stärkste negative Kontrast-Manipulation die Gedächtnisleistung der VersuchsteilnehmerInnen verschlechtert. Auch wurde keine Korrelation zwischen individueller Fähigkeit in kognitiver Kontrolle und Leistung in den Aufgaben zu (dis)fluenten Stimuli gefunden. Diese Ergebnisse stellen Theorien, die einen positive Zusammenhang zwischen disfluenten Stimuli und Gedächtnisleistung vorhersagen, in Frage und unterstützt Theorien, die einen solchen Effekt als „false-positives“ klassifizieren. Folgend sollte davon abgesehen werden disfluente Stimuli in Anwendungsfeldern, wie Lernen im Klassenraum, anzuwenden, besonders für visuelle Stimuli.