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CONTENT

1 Introduction

1.1 Problem

In cognitive tasks attention can be directed towards the environment (intake of the environment) or it can be directed towards internal processing (rejection of the environment). Thus, the direction of attention is directly related to task demands.

Already James (1890) differentiated between sensorial attention (i.e. attention to incoming sensory information) and intellectual attention (i.e. attention to inner thoughts, images, memories). Lacey (1959) formulated his intake-rejection hypothesis when he came across the effect of “directional fractionation” of autonomic response in a series of studies employing various stress inducing stimulus conditions. He argued that tasks requiring attention to the external environment (intake tasks) produced cardiac deceleration, whereas tasks requiring internally directed attention (rejection tasks) resulted in cardiac acceleration.

Even though attention in cognitive processing consists of several parallel and serial processes and some of these processes may be represented by DC potentials (Birbaumer, Elbert, Canavan, & Rockstroh, 1990), cortical DC potentials have received no attention with regard to the intake-rejection hypothesis, as formulated by Lacey (1959), so far. Therefore, this study aims at evaluating the effects of tasks requiring intake of the environment as opposed to tasks requiring the rejection of the environment on DC potentials.

Furthermore, as activity in the cardiovascular system has been associated with the understanding of attentional processes and as increased attention has been directed towards heart rate variability in the past decades as a measure of cardiovascular activity (Hansen, Johnsen, & Thayer, 2003), the intake-rejection dimension will be evaluated in terms of its effect on heart rate variability and heart rate as well. In order to take account for modality effects on the direction of attention, intake and rejection tasks in the verbal and figural modality will be examined.

1.2 An overview on experiments involving the intake-rejection paradigm

Lacey (1959) demonstrated that situations requiring attention to external tasks, in example a “Visual attention task”, in which subjects had to take note of the colors and patterns produced by flickering photic stimulation with instructions that they would be asked to describe them afterwards and an “Empathic listening condition”, in which subjects were instructed to listen attentively to a tape-recorded dramatic monologue of the thoughts and feelings of a severely injured and dying man, produced cardiac deceleration. Whereas situations that required internally directed attention and therefore rejection of the environment, in example a "Thinking task", which was a mental arithmetic task requiring the subjects to quickly solve a series of simple addition and multiplication problems in their heads, and a "Withstanding pain" task, in which subjects had to hold one foot in 4° C cold water for 75 seconds were accompanied by cardiac acceleration. However, all four stimulus conditions produced increases in palmar skin conductance. Lacey then hypothesized that the acceleration, accompanying environmental intake, and the deceleration, accompanying environmental rejection, of the heart rate facilitates environmental intake and rejection of the environment.

A follow-up experiment on directional fractionation of response, conducted by Lacey, Kagan, Lacey, and Moss (1963), was aimed at determining whether heart-rate decelerations would indeed be obtained in stimulus conditions requiring sustained attentiveness to the incoming stimuli and whether heart-rate accelerations would be obtained in stimulus conditions requiring selective "rejection" of stimuli. Furthermore, it was aimed at establishing if a continuum from "environmental intake" to "environmental rejection" does exist. As environmental rejection tasks a "Mental arithmetic task" (see description above), a "Reverse spelling task" (words were spelled aloud backwards and subjects had to mentally rearrange the letters and give the correct word), and a "Make up sentences task" (subjects were given a letter of the alphabet and had to think up meaningful and grammatically correct sentences of at least five words, in which each of the words in the sentence had to begin with the given letter) were used. As for environmental intake tasks, in the stimulus situation "Grass Photostimulator" subjects were stimulated by flashes and were instructed to note and detect the varying colors and patterns produced as they would be asked about that afterwards and in the "Drama" situation subjects had to listen to a tape-recorded monologue of the thoughts and feelings of a dying man. Consistent with the earlier results from Lacey (1959) cardiac acceleration was produced by the three stimulus situations that demanded cognitive problem-solving and therefore rejection of the environment, and cardiac deceleration was produced by the two stimulus situations that required sustained attentiveness to external, incoming stimuli and therefore environmental intake. In order to evaluate if a continuum from "environmental intake" to "environmental rejection" exists, the following two stimulus situations were used: "Rules of the game", in which subjects were required to listen to a tape recording of a set of rules for an imaginary card game trying to memorize the rules, knowing that they would be questioned about them afterwards. This task required the subject to attend to incoming stimuli, but also at the same time cognitive elaboration and storage of information was required. "Noise", in which the subjects were exposed to white noise at fluctuating loudness with peak intensities above 100 dB, while being instructed to attend (which should produce deceleration) to this very unpleasant stimulus (which should produce acceleration). "Rules of the game" indeed had an intermediate, balanced effect on heart rate. But "Noise", contrary to their expectations, produced cardiac deceleration.

Obrist (1963) tried to replicate these findings and employed three stimuli situations requiring rejection of the environment previously used by Lacey (1959) and Lacey et al. (1963), namely the Cold pressor test, White noise in varying intensity, and a task consisting of complex mental arithmetic problems. Three additional stimuli situations that had not been used in previous studies were selected as environmental intake tasks: "Colored slides", in which the subjects had to attend to colored landscape slides, "Auditory passage", in which the subjects had to listen to a short essay, and "Hidden faces", in which the subjects had to find hidden faces of people in a drawing. Consistent with Lacey's (1959) and Lacey's et al. (1963) results, Obrist reported heart rate acceleration for the "Cold pressor" and "Mental arithmetic" tasks and heart rate deceleration for the "Color slides", "Auditory passages", and "Hidden faces" tasks. Obrist found cardiac deceleration during exposure to white noise as well.

In subsequent experiments Lacey (1967) ascertained that only heart rate and blood pressure showed a distinct and dramatic difference between environmental intake and environmental rejection situations, whereas simultaneously recorded autonomic measures, such as palmar skin conductance, respiratory period, and inspiration-expiration ratios did not.

Lacey and Lacey (1974) varied the task difficulty, as they suggested that tasks used in earlier studies (i.e. Lacey, 1959; Lacey et al., 1963) such as looking at a flickering light or listening to a dramatic monologue might be perceived as less difficult than tasks such as "Mental arithmetic" or "Reverse spelling". Therefore the reported results could be attributed to task difficulty rather than to the difference between environmental intake and environmental rejection conditions. They therefore made the following adjustments to their tasks. The "Mental arithmetic" task was simplified by replacing the requirement for multiplication with a requirement for simple successive additions. To represent the "intake extreme" a more demanding task of "Tone detection" was chosen, in which the subjects were required to listen to a series of tones of 500 Hz while at the same time trying to detect "signal tones" of 513 Hz. To study intermediate effects the "Rules of the game" (see description above) task was used, as well as a task, in which the subjects had to simultaneously perform the "Tone detection" and the "Mental arithmetic” tasks. Moreover, subjects were asked to rate the absolute difficulty of the employed tasks on a five-point-scale and rank the tasks in regards to relative difficulty. Regardless of the difference in difficulty heart rate decreased during “Tone detection” and increased during “Mental arithmetic”, and the heart rate response to “Rules of the game” was intermediate between “Tone detection” and “Mental arithmetic” as expected.

1.3 The physiological basis of the intake-rejection hypothesis

Lacey (1967) explained those results with the baroreceptor-hypothesis. The baroreceptors are pressure-sensitive receptors in the carotid sinus, in the aortic arch, and the walls of the heart itself and participate in cardiovascular homeostasis (Schandry, 1998). Increases of blood pressure and of heart rate determine the frequency of impulses along visceral afferent feedback pathways from the baroreceptors, with this visceral afferent feedback being negative and inhibitory of motor responses and of EEG activity (Lacey & Lacey, 1974).

Animal experiments have shown that an increased baroreceptor activity leads to a decreased muscle tone, increased slow EEG activity, termination of drug-induced seizures, and threshold elevations for monosynaptic reflexes. One can therefore conclude that decreased baroreceptor activity would lead to opposite effects (Lacey & Lacey, 1974).

Cardiac alterations were, therefore, determined to be a modulating factor in central attentional processes (Carroll & Anastasiades, 1978).

1.4 Criticism and defense of the physiological hypothesis for the intake-rejection paradigm

Even though the psychophysiological findings of the Laceys and their associates (i.e. Lacey, 1959; Lacey, 1967; Lacey et al., 1963 etc.) have been replicated many times and their reliability is, therefore, not in question, the meaning attached to these results has evoked criticism (Carroll & Anastasiades, 1978). Carroll and Anastasiades (1978) gave a detailed account of studies voicing criticism of the Laceys’ interpretations of their findings. Verbalization seems to be an important factor to be considered. Campos and Johnson (1966, 1967, as cited in Carroll & Anastasiades, 1978) demonstrated that the imposition of a verbalization requirement on environmental intake tasks produced cardiac acceleration, whereas deceleration was produced in such tasks when no verbalization requirement was imposed. As a consequence Edwards and Alsip (1969, as cited in Carroll & Anastasiades, 1978) tried to unravel those two factors and employed intake and rejection tasks either with or without a verbalization requirement. They discovered that while three of the intake tasks in the non-verbalization condition were accompanied by heart rate deceleration, heart rate acceleration was found in the verbalization condition. However, all four rejection tasks produced cardiac acceleration in the condition with and without verbalization requirement. Therefore, Edwards and Alsip proposed the idea that the verbalization requirement leads to a superimposition of a rejection task over an intake task.

Furthermore, according to Carroll and Anastasiades (1978) the relative status of environmental rejection as the main factor in cardiac accelerations in tasks involving cognitive processing is to be considered. They suggested that heart rate accelerations during tasks involving mental work are associated with typical features of cognitive processing and not with rejection of the environment as originally proposed by Lacey and his associates (i.e. Lacey, 1959; Lacey, 1967; Lacey et al., 1963 etc.).

Affect and its implications on the intake-rejection dimension needs to be considered as well (Carroll & Anastasiades, 1978). Lacey et al. (1963) pointed out that an organism wants to take in pleasant stimuli from the environment and therefore this is accompanied by heart rate deceleration, whereas an organism wants to reject unpleasant stimuli which is thus accompanied by heart rate accelerations. Carroll and Anastasiades (1978) cited numerous studies revealing that unpleasantness and pleasantness are not reflected in directionally opposite heart rate changes, and that unpleasant stimuli are frequently accompanied by heart rate deceleration. Subsequently Lacey and Lacey (1974, as cited in Carroll & Anastasiades, 1978) modified their hypothesis and viewed unpleasantness as associated with cardiac acceleration to the extent that unpleasantness interacted with rejection of the environment. Furthermore, Carroll and Anastasiades (1978) criticized that in regards to the attentional demands of an unpleasant stimulus presentation several other factors have to be taken into account like in example the instructions given to the subjects (e.g. whether they are instructed to attend to the unpleasant stimulus), the adaptive significance of the unpleasant situation, and the subjects' general attitude and orientation towards unpleasant stimuli.

According to Carroll and Anastasiades (1978) the factor of response intention and its effect on heart rate changes in intake and rejections tasks has given rise to criticism as well. However, they argue that it is difficult to detangle response intention from attention. Lacey and Lacey (1970, as cited in Carroll & Anastasiades, 1978) employed a 30-sec time estimation procedure with reinforcement not provided immediately contingent on response execution, but delayed by 4.5 sec and therefore attempted to operationally distinguish intention to respond from attention. They found deceleratory cardiac changes in both conditions, but offered no suggestions why response intention should have deceleratory effects on heart rate.

Moreover, it has been criticized that the physiological basis of the Laceys' hypothesis (i.e. Lacey, 1967; Lacey & Lacey, 1974) is more than questionable. Even though the Laceys and their associates have cited various studies to support the physiological basis of their hypothesis (see i.e. Lacey, 1967 for a detailed account), Green (1980), Hahn (1973), and Carroll and Anastasiades (1978) have listed ample evidence opposing the baroreceptor hypothesis. The interested reader may view the above mentioned articles for an extensive overview.

Nevertheless the Laceys' findings (i.e. Lacey, 1959; Lacey, 1967; Lacey et al., 1963 etc.) have made some important positive contributions to the development of psychophysiological research (Hahn, 1973). Additionally, up until the late 70ies there have only been few studies with human subjects focusing on the association between cardiovascular and central nervous system activity (Walker & Sandman, 1979). Furthermore, direct evaluation of baroreceptor function in human subjects has been restricted (Reyes del Paso, González, & Hernández, 2004).

In spite of the voiced criticism, it is a fact that baroreceptors are important regulators of cardiovascular activity and also exert an inhibitory control on cortical arousal through an efferent feedback pathway from the cardiovascular to the central nervous system and therefore have implications on cognitive processing (Reyes del Paso et al., 2004).

Due to progress in technology Reyes del Paso et al. (2004) were able to investigate the different cognitive-attentional demands related to intake and rejection tasks on baroreceptor reflex sensitivity (BRS) and baroreceptor effectiveness index (BEI). They employed a Mental arithmetic task as a rejection task, a Memory task that required intake as well as rejection of the environment, and a Visual attention task as environmental intake condition. It was expected that tasks requiring environmental rejection lead to inhibition of the baroreceptor regulation of cardiovascular activity and the increase in cardiovascular activity resulting from baroreceptor inhibition decreases the cortical arousal through the feedback pathway from the cardiovascular system to the central nervous system (Rau, Pauli, Elbert, Birbaumer, & Brody, 1993, as cited in Reyes del Paso et al., 2004). As a consequence this inhibitory effect on the brain reduces the perception of environmental input through the inhibition of somatosensory pathways (Dworkin, Filewich, Miller, Craigmyle, & Pickering, 1979, as cited in Reyes del Paso et al., 2004) and internal cognitive elaboration is facilitated (Lacey and Lacey, 1970, as cited in Reyes del Paso et al., 2004). As expected, Reyes del Paso et al. (2004) found that BRS was lower in the environmental rejection condition (Mental arithmetic task) compared to the environmental intake condition (Visual attention task) and the Memory task, a task requiring both intake and rejection of incoming stimuli. BEI increased during the Visual attention task and this was hypothesized to be due to the predicted relative decrease in cardiovascular activity as a function of baroreceptor activity which consequently stimulates cortical activation. Overall BEI was a more sensitive parameter regarding baroreceptor activity in the intake condition and BRS showed more sensitivity in the rejection condition.

1.5 EEG activity

1.5.1 Direction of attention and EEG measures

Walker and Sandman (1979) investigated the relation between changes in heart rate and evoked potentials and showed that following stimulation with 20-msec flashes delivered at high, midrange, and low heart rate overall amplitudes of evoked responses in the right hemispheres were enhanced during low heart rate and the amplitudes in the left hemisphere were enhanced during high heart rate, suggesting that the relationship between heart rate and various behaviors may be a result of different types of activity occurring in the two cerebral hemispheres.

Tucker and Williamson (1984) reviewed asymmetric neural control in human self-regulation and proposed that a perspective on lateralized neural systems in active (internally directed) and receptive (directed towards the external environment) attention is provided by evidence on heart rate changes with attentional demands. They suggested that the withdrawal of attention from external input and the focusing on actively directed internal cognitive processes would seem to be facilitated by the internal control of activation. Furthermore, the demands on short-term memory and the need to monitor serial, sequential cognitive operations in these tasks would also draw on the redundancy bias of activation. When preparing for action the cardiovascular system needs to be primed to handle the anticipated metabolic load (Obrist, Webb, Sutterer, & Howard, 1970, as cited in Tucker & Williamson, 1984). Therefore, the evidence that adrenal activity is regulated by central dopaminergic pathways (Quick & Sourkes, 1977, as cited in Tucker & Williamson, 1984) may suggest how engaging the active attentional control of the motor readiness system increases heart rate (Tucker & Williamson, 1984). However, as suggested by Tucker and Williamson (1984) when the intake of environmental information is required a qualitatively different attentional mode prevails and the organism opens up sensory channels for receptive input. According to Pribram (1981, as cited in Tucker & Williamson, 1984) minimizing redundancy enables the brain to maximize its participation in the information of its immediate environment with norepinephrine playing an important role in the shifting of control of the current information flow to the outside. The motor system should be quiet in this attentional mode and central norepinephrine activity is associated with a reduction in muscle tone (Cools & Rossum, 1970, as cited in Tucker & Williamson, 1984). The heart rate deceleration during perceptual intake can be compared to the more phasic heart rate slowing during the orienting response to new stimuli (Graham & Clifton, 1966, as cited in Tucker & Williamson, 1984) and therefore both may reflect noradrenergic arousal. Moreover, animal studies (Tackett, Webb, & Privitera, 1981, as cited in Tucker & Williamson, 1984) have shown heart rate deceleration and a decrease in blood pressure to coincide with the release of norepinephrine in brain pathways. Tucker and Williamson (1984) concluded that the different forms of cognitive activity in the Laceys' research (i.e. Lacey, 1959; Lacey, 1967; Lacey et al., 1963 etc.) may have produced different effects on cardiovascular function because they engaged specific attentional control systems that have evolved in concordance with the demands for the autonomic support of motor operations. In addition, Tucker and Williamson (1984) hypothesized that hemispheric specialization for the two attentional modes – intake of the environment and rejection of the environment – leads to specificity in the cognitive processes indicated by cardiac functions.

Ray and Cole (1985) attempted to determine the role of attentional demands in regards to the intake-rejection dimension on EEG processes in two studies, one emotional and one cognitive. In their first experiment involving cognitive processing the intake-rejection dimension was crossed with left- and right-hemispheric processing. "Counting verbs in a passage" and "Finding the error in a mathematics problem" were used as intake-left-hemispheric tasks and a "Paper-folding task" and "Mooney facial closure task" were used as intake-right-hemispheric tasks. The rejection-left-hemispheric tasks were comprised of a "Mental arithmetic task" and "Creating sentences beginning with a certain letter", whereas the rejection-right-hemispheric tasks consisted of "Mental rotation of a geometric figure" and the "Visualization of an imaginary walk". For the second experiment on emotional processing intake-rejection demands were crossed with positively and negatively valenced tasks. The rejection tasks included "Remembering a happy and sad event from one's past" and "Imagining future pleasant and unpleasant events". The intake tasks comprised of the presentation of slides considered to elicit positive and negative affect. From these two experiments Ray and Cole concluded that attentional, cognitive, and emotional factors are differentially represented in terms of EEG frequency, hemisphere and location. The intake-rejection dimension was reflected in parietal areas for the middle frequencies including alpha in both experiments with more alpha activity occurring during rejection than during intake tasks in both hemispheres. Moreover, the interaction between attention (intake or rejection) and hemisphere was statistically significant in both studies. However, the task demands, cognitive as well as emotional, were reflected in beta activity. Ray and Cole therefore concluded that EEG alpha activity is important regarding its ability to reflect attentional processes.

Valentino and Dufresne (1991) extended Ray and Cole’s (1985) experiment by including additional electrode sites, adding a resting condition with eyes closed, and using an auditory intake task, instead of a visual intake task, to investigate whether the previous findings can be extended across sensory modalities. Bilateral EEG coherence was measured as well in order to investigate the influence of asymmetry more extensively. Compared to the resting condition, both attention tasks caused a shift in alpha symmetry ratios toward increased power in the right hemisphere, especially at temporal locations. Additionally, they found a higher alpha power during tasks requiring acceptance of the environment than during tasks requiring rejection of the environment, and therefore being opposite to the relationship found by Ray and Cole (1985).

Harmony et al. (1996) compared changes in EEG activity during a mental task requiring attention to internal processing (rejection task: Mental calculation task) and a control stimulus with the same physical characteristics as the mental calculation task and reported an increase in delta activity related to the rejection of the environment during the performance of a mental task.

Cooper, Croft, Dominey, Burgess, and Gruzelier (2003) investigated the relation between alpha and internally (rejection of the environment) versus externally (intake of the environment) directed attention using mental imagery versus sensory-intake paradigms in combination with an increase in task demands in two experiments. They reported a relationship between alpha and both attentional factors and increased task demands with alpha amplitudes being greater at various locations during internally directed attention and during increased task load. These results were suggested as an active inhibition necessary for internally driven mental operations and therefore necessary for the rejection of the environment.

In a follow-up study Cooper, Burgess, Croft, and Gruzelier (2006) extended and improved their research on the intake-rejection-hypothesis by matching sensory inputs in the stimulus intake and rejection tasks to control for effects other than due to the experimental manipulation. They once more reported greater alpha power during tasks requiring rejection of the environment, as opposed to tasks requiring intake of the environment.

1.5.2 DC potentials

EEG recordings provide information on voltage fluctuations that appear on the scalp due to the electrical activity of the brain. An EEG comprises contributions from low- and high-frequency sources. The relative occurrence of various frequency components can be determined with spectral analysis. Conventionally, EEG activity is described in terms of frequency bands: alpha (8-13 Hz), beta (>13 Hz), theta (5-8 Hz), and delta (1-5 Hz) activity. However, very low-frequency contributions of less than 1 Hz have received comparably very little attention so far. There is always a sustained potential difference between scalp electrodes reaching as high as many millivolts. This potential can change by any hundreds of microvolts in the course of a few minutes and by many millivolts over the course of hours. These slow potential changes contain important electrophysiological correlates of cognition. (Pleydell-Pearce, 1994)

Some of the terms being used for this slow cortical bioelectrical activity are standing potentials, steady potentials, sustained potentials, slow potential changes (Caspers, 1974, as cited in Trimmel, 1990). Caspers, Speckmann, and Lehmenkuehler (1984, as cited in Trimmel, 1990) suggested that all bioelectrical events that can be recorded with DC amplifiers should be referred to as DC potentials, derived from “direct current”, even though Caspers actually refers to “direct coupled amplifiers”.

Thus, DC potentials include slow as well as fast field potentials (Speckmann & Elger, 1999). Furthermore, Caspers (1974, as cited in Trimmel, 1990) proposed that all potential changes ranging from 0 to 0.5 Hz, and therefore all potentials above 500 msec, should be termed “DC potentials”.

DC potentials can be differentiated in tonic and phasic DC potentials. The contingent negative variation (CNV) and the readiness potential can be regarded as phasic DC potentials evoked by a specific event (i.e. a warning stimulus) and reflect processes associated with expectancy or with preparation for a motor response, whereas sustained periods of cognitive load are associated with rather more tonic shifts in surface negativity (Pleydell-Pearce, 1994). Phasic shifts therefore usually are in the seconds range, whereas tonic shifts can be observed over a matter of minutes (Bauer, 1998).

DC potential shifts are considered to be mainly of neuronal origin (Birbaumer et al., 1990; Caspers, Speckmann, & Lehmenkuehler, 1984; Roitbak, 1993; Schmitt, Mölle, Marshall, & Born, 2000) generated by cortical structures close to the recording site and reflect the activation and deactivation of localized cortical cell assemblies (Marshall, Mölle, Fehm, & Born, 1998; Rösler, Heil, & Röder, 1997) with underlying complex interactions between the cortex, thalamus, RF, and the basal ganglia (Birbaumer, et al., 1990; Lamm et al., 2001). It has been discussed that negative DC potential shifts are a sign of higher excitability and therefore reflect cortical activation (Bauer & Nirnberger, 1981; Fuster, 1973; Fuster & Alexander, 1971; Rösler, et al., 1997; Stamm & Rosen, 1972), whereas positive DC potential shifts are a sign of reduced excitability and therefore reflect cortical inhibition (Marczynski & Karmos, 1978; Rowland, 1974; Rösler et al., 1997).

1.5.2.1 DC potentials and cognitive processing

DC potential shifts are closely related to the investigated core cognitive processes (Bauer, 1998).

Trimmel, Kundi, Binder, Groll-Knapp, and Haider (1996) showed a location-independent and distinct positive DC shift in mental load versus no mental load conditions. Furthermore, Trimmel and Poelzl (2006) found a positive shift for mental load by background noise.

Rösler et al. (1997) reported pronounced negative slow waves predominating over the posterior part of the scalp in mental rotation tasks. Moreover, they found a larger amplitude of the negative slow wave with increasing task difficulty. They also suggested that slow waves reflect different stages of information processing.

Pleydell-Pearce (1994) reported significantly higher negative DC potentials over posterior parietal areas in a word processing task requiring divided attention compared to a word processing task requiring focused attention. Furthermore, he demonstrated that prolonged periods of task demand lead to sustained elevations in scalp-surface negativity.

A negative shift in DC potentials at nearly all locations in computerized tasks versus a positive shift in paper pencil tasks was demonstrated by Trimmel, Strässler, and Knerer (2001). These results were interpreted as an indication of mental load and effort triggered by additional attentional and controlling processes in computerized tasks.

1.5.3 EEG and modality of tasks

Effects of different types of modality of tasks have largely been evaluated in regards to gender differences and lateralization.

Moore and Haynes (1980) examined gender effects of verbal and non-verbal stimuli on alpha hemispheric asymmetries and found less alpha in the right hemisphere for non-verbal tasks and less left-hemispheric alpha for verbal tasks with females showing significantly more lateralization during the tasks compared to males.

Ornstein, Johnstone, Herron, and Swencionis (1980) demonstrated that most of the differences in EEG patterns between verbal and non-verbal tasks were accounted for by differences in right hemisphere engagement.

Rugg and Dickens (1982) reported lower alpha power for verbal and visuo-spatial tasks compared to a resting condition, but higher theta power during task performance with higher epochs recorded during the visuo-spatial as opposed to the verbal task in the right hemisphere.

Kashihara and Ichitani (1987) evaluated EEG changes during the performance of verbal and figural tasks and demonstrated that at frontal and occipital regions right hemisphere dominance of the alpha component was more distinct during the verbal tasks than during the non-verbal tasks, whereas at occipito-temporal regions left hemispheric dominance was found during the non-verbal tasks.

1.6 Cardiovascular activity

Lacey and colleagues demonstrated extensively that attentional processes are associated with cardiovascular activity (see i.e. Lacey, 1959; Lacey et al., 1967; Lacey & Lacey, 1974). It is therefore crucial to take the cardiovascular system into account when studying attentional processing. Whereas Lacey and colleagues put their focus on heart rate and blood pressure activity, the attention has been directed to the fluctuation in the inter-beat-interval between normal heartbeats over the last decades, referred to as heart rate variability (HRV) (Hansen et al., 2003). This beat-to-beat variability in heart rate reflects dynamic interactions between excitatory and inhibitory autonomic control mechanisms (Critchley et al., 2003).

As the heart is innervated dually by the autonomic nervous system heart rate increases are related to relative increases in sympathetic activity, whereas heart rate decreases are linked to relative increases in parasympathetic activity. Consequently relative sympathetic increases shorten the inter-beat-interval and relative parasympathetic increases lengthen the inter-beat-interval (Lane et al., 2009).

1.6.1 Measures of heart rate variability

Heart rate variability can be evaluated amongst others with time domain and frequency domain methods. See Table 1 for selected statistical time-domain measures of heart rate variability (Task Force, 1996).

Table 1. Selected statistical time-domain measures of HRV.

Variable	Units	Description
SDNN	ms	Standard deviation of the NN interval, reflecting all cyclic components responsible for variability in the recording period.
SDANN	ms	Standard deviation of the averages of NN intervals for all 5-minute segments of the entire recording.
RMSSD	ms	Square root of the mean squared differences of successive NN intervals.
SDNN index	ms	Mean of the standard deviations of all NN intervals for all 5-minute segments of the entire recording.
SDSD	ms	Standard deviation of differences between successive NN intervals.
NN50 count		Number of pairs of successive NN intervals differing by more than 50 ms in the entire recording; three variants are possible: counting all such NN intervals pairs or only pairs in which the first or the second interval is longer.
pNN50	%	NN50 count divided by the total number of NN intervals.

See Table 2 for selected frequency domain measures of heart rate variability for short-term-recordings (Task Force, 1996).

Table 2. Selected frequency domain measures of HRV.

Variable	Units	Description	Frequency range
Total power	ms^2	Variance of all NN intervals over the temporal segment.	$\approx \leq 0.04$ Hz
VLF	ms^2	Power in the very low frequency range.	≤ 0.04 Hz
LF	ms^2	Power in the low frequency range.	0.04-0.15 Hz
LF norm	n. u.	LF power in normalized units - LF / (Total power-VLF) x 100.	
HF	ms^2	Power in the high frequency range.	0.15-0.4 Hz

Variable	Units	Description	Frequency range
HF norm	n. u.	HF power in normalized units. HF / (Total power-VLF) x 100.	
LF/HF		LF in ms^2 divided by HF in ms^2.	

However, it is important to note that VLF assessed from recordings ≤ 5 min should be avoided. In long-term recordings an ultra-low frequency component and α (slope of the linear interpolation of the spectrum in a log-log scale) can be determined as well (Task Force, 1996).

The low frequency component can be largely attributed to sympathetic nervous activity (Pagani et al., 1986; Eckberg, 1997; Montano, Porta, & Malliani, 2001, as cited in Critchley et al., 2003), whereas the high frequency component is attributed to parasympathetic, vagally mediated activity (Montano et al., 2001, as cited in Critchley et al., 2003). The LF/HF ratio is considered to reflect sympatho/vagal balance or sympathetic modulations (Task Force, 1996).

pNN50 and RMSSD are sensitive and highly correlated indices of vagal influences and therefore estimate high frequency variations in heart rate. Moreover, many time- and frequency domain parameters are strongly correlated with each other (Task Force, 1996). Table 3 lists time domain variables and their approximate frequency domain correlate (Task Force, 1996).

Table 3. Approximate correspondence of time domain and frequency domain measures.

Time domain variable	Approximate frequency domain correlate
SDNN	Total power
SDANN	ULF
SDNN index	Mean of 5 min total power
RMSSD	HF
SDSD	HF
NN50 count	HF
pNN50	HF

The interested reader may refer to the guidelines on heart rate variability proposed by the Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996) to get more information on the various heart rate variability measures, technological requirements, physiological correlates of heart rate variability, changes of heart rate variability related to specific pathologies, and modifications of heart rate variability by specific interventions.

1.6.2 Direction of attention and heart rate variability

Middleton, Sharma, Agouzoul, Sahakian, and Robbins (1999) investigated the effects of tests of planning and attention on measures of heart rate variability. Their cognitive tasks consisted of RVIP (test of sustained attention with small working memory component), set shifting (ID/ED shift paradigm), Tower of London (test of planning) and spatial working memory (self-ordered search task). They found significant differences between the tasks with significant post hoc contrasts between RVIP and each of Tower of London and spatial working memory for heart rate variability. Additional spectral analysis extended these variability findings with significantly different heart rate variability fluctuations at frequencies around 0.1 Hz (spectral power in the 0.0547-0.156 Hz range) due to lower values during each of the “attentional” tasks than during the “planning” tasks. Middleton et al. (1999) discussed their findings in the context of the intake-rejection hypothesis. They interpreted the RVIP and set shifting task as comparable to tasks employed by the Laceys and their associates (i.e. Lacey, 1959; Lacey et al., 1963; Lacey & Lacey, 1974) requiring intake of the environment and the Tower of London and spatial working memory task as comparable to the Laceys’ tasks requiring rejection of the environment.

1.6.3 Cognitive processing and heart rate variability

Even though up until now only Middleton et al. (1999) incorporated measures of HRV into the intake-rejection dimension, HRV and attentional processes and HRV and cognitive processing in general have been examined by various researchers.

Porges and Raskin (1969, as cited in Hansen et al., 2003) showed that HRV was significantly decreased during sustained attention and Backs and Ryan (1992, as cited in Hansen et al., 2003) found reduced RMSSD as attentional demands extended from focused to divided attention.

In an information encoding and retrieval experiment it was demonstrated that deeply encoded items were accompanied by increased suppression of heart rate variability during recognition (Vincent, Craik, & Furedy, 1996).

In regards to task difficulty HRV was found to be only sensitive to large changes in task difficulty (Veltman & Gaillard, 1998).

Hansen et al. (2003) found a suppression of RMSSD during a working memory task and a continuous performance task requiring sustained attention in male sailors from the Royal Norwegian Navy. Moreover, subjects with a high HRV (as measured by RMSSD) showed more correct responses in the working memory test than the low HRV group. Additionally, the HRV group showed faster mean reaction time, more correct responses, and fewer errors in the continuous performance test.

Gianaros, Van der Veen, and Jennings (2004) found decreased HF during a verbal and spatial working-memory task compared to a perceptual motor-control task, suggesting that the working-memory task reduced cardiac parasympathetic activity.

Yu, Zhang, Xie, Wang, and Zhang (2009) showed that LF/HF, nuLF (LF in normalized units) were significantly decreased and heart rate was significantly higher during a mental arithmetic task compared to the control condition, indicating an increase in sympathetic activity and decrease in parasympathetic activity during the mental arithmetic task.

1.7 Summary of research, research hypotheses, and additional research questions

The intake-rejection paradigm has been studied extensively in regards to its effects on heart rate, other autonomic measures (see i.e. Lacey, 1959; Lacey et al., 1963; Lacey & Lacey, 1974; Obrist, 1963), and EEG activity in the alpha, beta, and delta frequency bands (see i.e. Cooper et al, 2006; Cooper et al., 2003; Harmony et al., 1996; Ray & Cole, 1985 etc.). However, cortical DC potentials, even though they have been studied in regards to various attentional demands and are known to provide a measure of long-term activity in underlying cortical regions (Pleydell-Pearce, 1994), have received no attention in context with the intake-rejection hypothesis, as formulated by Lacey (1959), so far. Furthermore, only Middleton et al. (1999) have studied the intake-rejection paradigm in connection with heart rate variability up until now.

The present study, therefore, aims at evaluating the effects of tasks requiring the rejection of the environment as opposed to tasks requiring the intake of the environment on brain DC potentials and measures of heart rate variability. Moreover, in accordance with the Laceys' original work (i.e. Lacey, 1959; Lacey, 1967; Lacey et al., 1963 etc.), the effects on heart rate will be examined as well. Even though modality effects on EEG activity have largely been studied in regards to lateralization and gender (i.e. Kashihara & Ichitari, 1982; Moore & Haynes, 1980; Rugg & Dickens, 1982), in order to take account for modality effects verbal and figural environmental intake and rejection was evaluated, thus exploring whether the findings differ across modalities.

1.7.1 Research hypotheses

1.7.1.1 DC potentials

Based on Trimmel and Poelzl (2006), where a positive DC shift was associated with the rejection of background noise in an attention task and as indicated by Cooper et al. (2003) suggesting inhibition processing during attention directed towards internal processing it was expected that tasks requiring rejection of the environment are associated with more positive DC potential changes.

1.7.1.2 Heart rate

Based on Lacey (1959), Lacey et al. (1963), and Lacey & Lacey (1974), it was expected that the environmental intake condition produces heart rate deceleration compared to the baseline heart rate and that the environmental rejection condition produces heart rate acceleration compared to the baseline heart rate.

1.7.1.3 Heart rate variability

Based on Middleton et al. (1999), it was expected that HRV has higher values in the environmental rejection condition than in the environmental intake condition.

1.7.2 Additional research questions

It will be illustrated if the effect of the direction of attention condition on DC potential shifts, heart rate, and parameters of heart rate variability differs within different types of modality.

2 Method

2.1 Subjects

Forty-eight right-handed healthy adults participated in the study, which were recruited from among students attending lectures and courses held by Ao. Univ.-Prof. Trimmel at the University of Vienna and the Medical University of Vienna. The subjects participated voluntarily and received a course credit for participation. Due to hardware problems two subjects had to be excluded from data analysis. Therefore, the sample was composed of 40 females and 6 males ranging in age from 19 to 37 years, with a mean age of 24 ± 4 years. See Table 4 for sample characteristics.

Table 4. Sample characteristics in regards to age.

	N	Mean	SD	Min.	Max.
Male	6	26	5	23	37
Female	40	23	4	19	33
Total	46	24	4	19	37

Note. N = number, SD = Standard Deviation.

2.2 Design

The study was designed as quasi-experimental laboratory study. A noise condition (no noise, white noise, irrelevant speech) was conceptualized, but will not be included in the following data analysis. Dependent variables were DC potential shifts, heart rate, and parameters of heart rate variability and independent variables were direction of attention, modality, recording location, time on task, and noise.

Not taking the noise condition into account, in this thesis, the study was based on the following designs:

2.2.1 DC potentials

The experiment was based on a 2 (direction of attention) x 2 (modality) x 3 (recording location) x 3 (time) repeated measures ANOVA design.

2.2.2 Heart rate

The experiment was based on a one-way (condition: baseline, attention task verbal, attention task figural) repeated measures ANOVA design.

2.2.3 Heart rate variability

The experiment was based on a 2 (direction of attention) x 2 (modality) repeated measures ANOVA design.

2.3 Research conditions and material

2.3.1 Direction of attention condition

In accordance with the author’s research on tasks requiring intake and rejection of the environment, two intake and two rejection tasks, with a figural and a verbal component to investigate direction of attention within different modalities, were developed (referred to as IV for verbal intake, IF for figural intake, RV for verbal rejection, and RF for figural rejection). Due to the fact that a noise condition was included in the study as well, parallel versions (from now on referred to as A and B) of the respective intake and rejection tasks were created.

Each task consisted of two parts:

- Attention task (computerized)
- Examination of task execution (paper and pencil)

Attention tasks were programmed with Eventplayer 5.1, a computer program developed by Ing. Strässler, the computer technician employed by the Institute for Environmental Hygiene, and presented to the subjects via laptop (ACER Travelmate 291 LCi) with a distance of approximately 80 cm between subject and laptop screen. The visual angle measured 22 °C horizontally and 16 °C vertically.

Following each computerized task the subjects' task execution was examined by filling in answer sheets in order to verify that subjects had followed the instructions for the attention tasks and that their attention, therefore, was indeed internally or externally directed.

All attention tasks and their respective examination of task execution were pre-tested among a group of 10 students and adjusted accordingly.

2.3.1.1 Intake tasks

- Verbal intake (IV) - "Listening task"

Conforming with Lacey (1959), Lacey et al. (1963), and Obrist (1963) a listening task was chosen. From the Lern- und Merkfähigkeitstest (Seyfried, 1990), a German memory test, a memory exercise was selected. This memory exercise consists of a short text about a fictitious state in Africa. A series of facts about this fictitious state are presented in the text. In the original Lern- und Merkfähigkeitstest one has 10 minutes to try to read and memorize these facts. Within the context of this study, the text was read (spread out over 90 seconds) and recorded as mp3 file by a friend of the author, who is a professional musician and therefore had access to a recording studio. The sound level of the listening task was set to a mean sound level of 74 dB(A) at the head of the participants.

Subjects were asked to listen to the text and try to memorize as many facts as possible about the fictitious state. It was specifically pointed out to the subjects that during this task one could easily forget to keep one's eyes open, therefore a small black fixation cross on a grey background was shown on the computer screen throughout the entire task, and subjects were told that, if they wanted, they could focus on the black cross during the task. See Figure 1 for an exemplary screenshot.

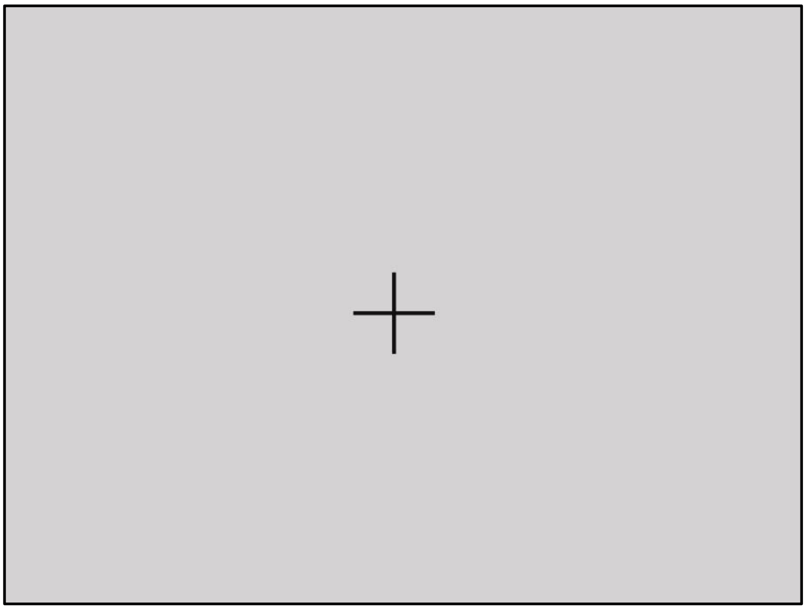

Figure 1. Exemplary screenshot “Listening task”.

Subjects were told that afterwards they had to answer several questions concerning these facts. Subsequently task execution was examined with an answer sheet, on which subjects had to write down the correct answers. See Appendix A for Figure A 1 for an example of this answer sheet.

- Figural intake (IF) - “Recognizing photographs of trees”

Following Obrist (1963) who had subjects view colored landscape slides to examine the effects of attention to the external environment, the author took several 100 photos of trees from various locations around Vienna in April and May 2008. Overall 40 photos were selected, 20 for each of the two parallel versions A and B. 10 of those 20 photos were presented to the subjects, displayed over approximately 75 % of the computer screen, over a time period of 90 seconds, with a presentation time of 9 seconds for each photo (see Appendix A Figure A 2 and Figure A 3). The participants were instructed to watch the photos carefully and to try to memorize them and were told that afterwards the photos had to be recognized among a series of tree photos. See Figure 2 for an exemplary screenshot.

Figure 2. Exemplary screenshot “Recognizing photographs of trees”.

Subsequently, task execution was examined by using a laminated template with 20 photos, 10 of those being distractor photos and 10 being the photos to be recognized. Subjects had to indicate using an answer sheet if they thought that the respective photos had just been included in the computer presentation. See Appendix A for Figure A 4, Figure A 5, and Figure A 6 for an example of the answer sheet and the templates used for parallel version A and B.

2.3.1.2 Rejection tasks

- Verbal rejection (RV) - “Creating words”

The verbal rejection task was based on the “Make-up sentences task” construed by Lacey et al. (1963) and a task (Word beginnings) was taken from the “Verbaler Kreativitäts-Test” (Schoppe, 1975). The participants were presented a word beginning (one syllable: ver- for parallel version A and zer- for parallel version B) for 90 seconds via computer screen and were asked to think of as many words as possible beginning with this syllable and to try to memorize these words. Subjects were told that they had to write down these words afterwards. See Figure 3 for an exemplary screenshot.

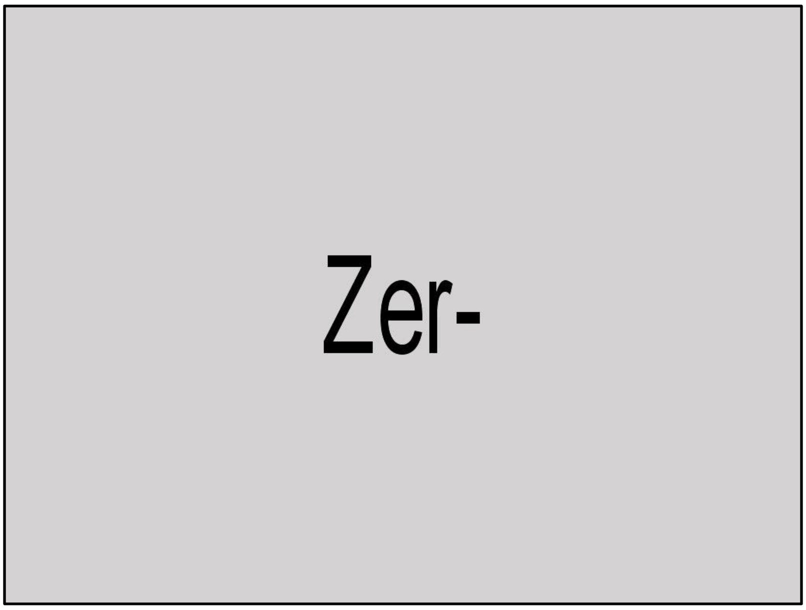

Figure 3. Exemplary screenshot “Creating words“.

In concordance with the other tasks, task execution was examined subsequently with the subjects listing their created and memorized words on an answer sheet (see Appendix A for Figure A 7). Subjects were explicitly instructed to only write down the words memorized during the task and to not come up with new words during the examination of task execution.

- Figural rejection (RF) - “Picture completion”

The figural rejection task was loosely based on Ray and Cole’s (1985) “Mental rotation” task. But instead of using mental rotation exercises, incomplete figures were taken from the task “Picture completion” from the Torrance Tests of Creative Thinking (Torrance, 1974). The first four figures of Torrance’s parallel form A were used for parallel version A and the first four figures of Torrance’s parallel form B were used for parallel version B. These four figures were presented on the computer screen all at once for 90 seconds, and subjects were instructed to try and complete those figures to make up an interesting object or picture in their heads and to think of a title for each of their creations. Furthermore, they were told that they had to complete the same figures on paper after the computer presentation. See Figure 4 for an exemplary screenshot.

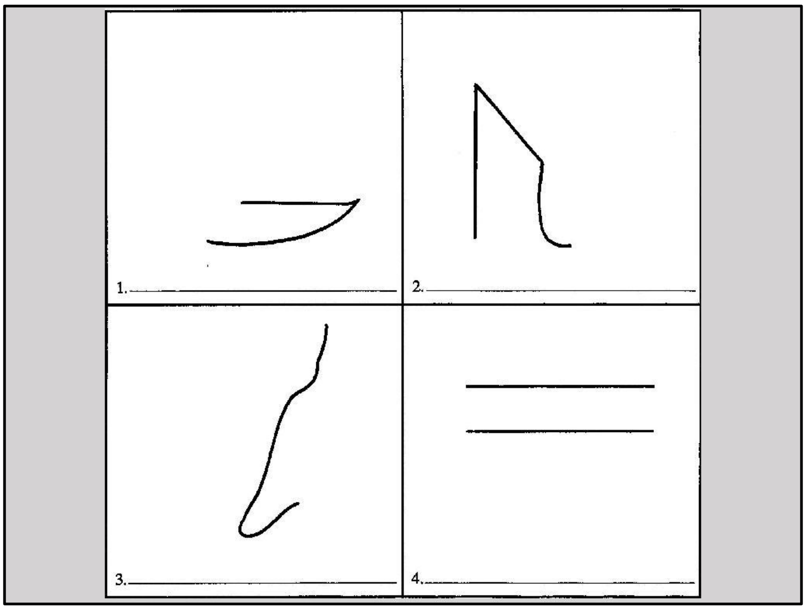

Figure 4. Exemplary screenshot “Picture completion”.

Following the computer presentation task execution was examined. The participants were given an answer sheet with the same four incomplete figures copied on them and asked to complete and name the figures according to their creations during the computer task.

2.3.2 Noise condition

A noise condition was included in this study as well, but the data coming from this additional condition was not analyzed for this thesis. All subjects were tested in a no noise condition, the first 24 participants were additionally subjected to a white noise condition and the second 24 participants were additionally exposed to an irrelevant speech condition.

In white noise the noise power is distributed equally over all audible frequencies of 16 - 20 KHz. The white noise used for this study was generated using CoolEdit (Version 2.1, Sytrillium).

For the irrelevant speech condition a recording of an Austrian comedian (Josef Hader) was used playing backwards.

The two sounds were presented by loudspeakers located 2.5 m in front of the subjects with a mean sound level 65 dB(A) measured at the head position of the participants.

2.3.3 Questionnaires

Because a noise condition had been included in the design, subjects had to complete a questionnaire on dealing with noise exposure, developed by Prof. Trimmel (2009). In addition the NASA Task load index (Hart & Staveland, 1988) was administered twice, once after the noise and once after the no noise condition to compare the subjects' evaluation of mental load between the two conditions. Additionally, subjects were asked to rate their motivation and mood on a 21-point-scale.The results of those questionnaires were not analyzed for this thesis.

2.3.4 Tutorial

For each type of intake and rejection task a short tutorial was created resembling the created attention tasks and their respective examination of task execution. The tutorial was pre-tested as well and adjusted accordingly.

2.4 Procedure

The present study (Study II) always followed a study (Study I) on perception of visual stimuli in regards to DC and event related potentials as well as parameters of heart rate variability, where subjects had to rate their perception on visual stimuli. No cognitive requirement was included in Study I. After Study I participants were given a break of 15 minutes.

Both studies were conducted over a period of four months from March 2009 until June 2009 and took place in the EEG laboratory of the Institute for Environmental Hygiene of the Medical University of Vienna. Subjects were tested in two time blocks, either from 9.00 am to 1.00 pm or from 2.00 pm to 6.00 pm.

Two investigators were present during each study, with one investigator sitting next to the subject giving the instructions, starting the computerized tasks at the correct time intervals and handing out the respective answer sheets for the examination of the task execution after the computerized task. The second investigator sat next to the first investigator, writing down times of task start and completion and indicating to the first investigator when to start the computer tasks.

In order to avoid artifacts resulting from instabilities in regards to the electrolyte-skin interface, electrodes were applied at least 60 minutes before recording started for Study I (Trimmel, 1990; Trimmel, Groll-Knapp, & Haider, 1982). Electrode offsets were verified to be below a threshold of ± 50 mV before both studies.

After EEG and ECG electrode application subjects were seated in front of the laptop. Participants were instructed to keep as still as possible and try to move legs and arms as little as possible during the computer tasks and to not talk in order to keep movement artifacts at a minimum. Ametropic subjects were asked to wear their glasses or contact lenses for vision correction during the test session. The room temperature was held constant for all of the participants at 22 to 24 °C with central heating and air conditioning.

The sequence of both noise conditions (no noise, noise), the sequence of attention tasks (IF, IV, RF, RV) and the two parallel versions (A and B) used for the attention tasks were balanced over all subjects in order to avoid sequence effects.

See Table 5 for sequence of noise conditions, used parallel versions, and sequence of attention tasks for all subjects.

Table 5. Sequence of noise conditions, used parallel versions, and sequence of attention tasks for all subjects.

Subject no.	Block 1			Block 2		
	Noise Condition	Parallel Version	Sequence of Att. tasks	Noise Condition	Parallel Version	Sequence of Att. tasks
1	WN	A	Iv, If, Rv, Rf	NN	B	Rf, Iv, If, Rv
2	NN	A	Iv, If, Rf, Rv	WN	B	Rf, Rv, If, Iv
3	WN	B	Iv, Rv, If, Rf	NN	A	If, Iv, Rf, Rv
4	NN	B	Iv, Rv, Rf, If	WN	A	Rf, If, Rv, Iv
5	WN	A	Iv, Rf, If, Rv	NN	B	Iv, Rv, Rf, If
6	NN	A	Iv, Rf, Rv, If	WN	B	Rv, If, Iv, Rf
7	WN	B	If, Iv, Rv, Rf	NN	A	Rv, If, Rf ,Iv
8	NN	B	If, Iv, Rf, Rv	WN	A	Rf, Iv, Rv, If
9	WN	A	If, Rv, Iv, Rf	NN	B	Rf, If, Iv, Rv
10	NN	A	If, Rv, Rf,Iv	WN	B	Rv, Rf, Iv, If
11	WN	B	If, Rf, Iv, Rv	NN	A	Iv, Rf, If, Rv
12	NN	B	If, Rf, Rv, Iv	WN	A	If, Iv, Rv, Rf
13	WN	A	Rv, Iv, If, Rf	NN	B	Iv, If, Rf, Rv
14	NN	A	Rv, Iv, Rf, If	WN	B	Iv, Rf, Rv, If
15	WN	B	Rv, If, Iv, Rf	NN	A	If, Rv, Iv, Rf
16	NN	B	Rv, If, Rf, Iv	WN	A	Iv, Rv, If, Rf

Subject no.	Block 1			Block 2		
	Noise Condition	Parallel Version	Sequence of Att. tasks	Noise Condition	Parallel Version	Sequence of Att. tasks
17	WN	A	Rv, Rf, Iv, If	NN	B	Rf, Rv, Iv, If
18	NN	A	Rv, Rf, If, Iv	WN	B	If, Rf, Iv, Rv
19	WN	B	Rf, Iv, If, Rv	NN	A	Rv, Iv, If, Rf
20	NN	B	Rf, Iv, Rv, If	WN	A	Iv, If, Rv, Rf
21	WN	A	Rf, If, Iv, Rv	NN	B	If, Rv, Rf, Iv
22	NN	A	Rf, If, Rv, Iv	WN	B	Rv, Rf, If, Iv
23	WN	B	Rf, Rv, Iv, If	NN	A	If, Rf, Rv, Iv
24	NN	B	Rf, Rv, If, Iv	WN	A	Rv, Iv, Rf, If
25	IS	A	Iv, If, Rv, Rf	NN	B	Rf, Iv, If, Rv
26	NN	A	Iv, If, Rf, Rv	IS	B	Rf, Rv, If, Iv
27	IS	B	Iv, Rv, If, Rf	NN	A	If, Iv, Rf, Rv
28	NN	B	Iv, Rv, Rf, If	IS	A	Rf, If, Rv, Iv
29	IS	A	Iv, Rf, If, Rv	NN	B	Iv, Rv, Rf, If
30	NN	A	Iv, Rf, Rv, If	IS	B	Rv, If, Iv, Rf
31	IS	B	If, Iv, Rv, Rf	NN	A	Rv, If, Rf ,Iv
32	NN	B	If, Iv, Rf, Rv	IS	A	Rf, Iv, Rv, If
33	IS	A	If, Rv, Iv, Rf	NN	B	Rf, If, Iv, Rv
34	NN	A	If, Rv, Rf,Iv	IS	B	Rv, Rf, Iv, If
35	IS	B	If, Rf, Iv, Rv	NN	A	Iv, Rf, If, Rv
36	NN	B	If, Rf, Rv, Iv	IS	A	If, Iv, Rv, Rf
37	IS	A	Rv, Iv, If, Rf	NN	B	Iv, If, Rf, Rv
38	NN	A	Rv, Iv, Rf, If	IS	B	Iv, Rf, Rv, If
39	IS	B	Rv, If, Iv, Rf	NN	A	If, Rv, Iv, Rf
40	NN	B	Rv, If, Rf, Iv	IS	A	Iv, Rv, If, Rf
41	IS	A	Rv, Rf, Iv, If	NN	B	Rf, Rv, Iv, If
42	NN	A	Rv, Rf, If, Iv	IS	B	If, Rf, Iv, Rv
43	IS	B	Rf, Iv, If, Rv	NN	A	Rv, Iv, If, Rf
44	NN	B	Rf, Iv, Rv, If	IS	A	Iv, If, Rv, Rf
45	IS	A	Rf, If, Iv, Rv	NN	B	If, Rv, Rf, Iv

Subject no.	Block 1			Block 2		
	Noise Condition	Parallel Version	Sequence of Att. tasks	Noise Condition	Parallel Version	Sequence of Att. tasks
46	NN	A	Rf, If, Rv, Iv	IS	B	Rv, Rf, If, Iv
47	IS	B	Rf, Rv, Iv, If	NN	A	If, Rf, Rv, Iv
48	NN	B	Rf, Rv, If, Iv	IS	A	Rv, Iv, Rf, If

Note. Noise condition: NN = no noise, WN = white noise, IS = irrelevant speech; Attention task: IV = verbal intake, IF = figural intake, RV = verbal rejection, RF = figural rejection.

The test session for Study II on direction of attention was started off with a six minute baseline for cardiovascular parameters. During the baseline subjects were given a short questionnaire on dealing with noise exposure and after completing the questionnaire were engaged in light conversation by the two investigators.

Afterwards, a verbal instruction was given to the subjects and all participants underwent a tutorial for each attention task and their respective subsequent examination of task execution until full comprehension of task demands.

The experimental procedure was started off with the subjects sitting as motionless as possible in front of a grey computer screen for 30 seconds. Subsequently Block 1 was started off with Task 1. Each task consisted of a baseline for the DC potentials of 30 seconds (with the subjects sitting as motionless as possible in front of a grey screen), a short instruction for 20 seconds, to remind subjects of the task requirements, followed by the attention task itself for 90 seconds and the examination of the task execution for 90 seconds. After the examination of the task execution of Task 4 subjects had to sit as motionless as possible in front of a grey computer screen for one minute. During a break of six minutes after Block 1 subjects were administered the NASA Task Load Index and after completion were allowed to interact with the investigators. Before the start of Block 2 subjects had to sit as motionless as possible in front of a grey computer screen for 30 seconds again. Then Block 2 was started off with the baseline for Task 5 etc. Following the examination of the task execution of Task 8 participants had to sit as motionless as possible for one minute. Afterwards, they were administered the NASA Task Load Index once again. See Table 6 for the detailed procedure.

Table 6. Procedure details.

Baseline for cardiovascular parameters (at the same time administration of noise questionnaire)			6 Min.
Verbal instruction and tutorial			≈ 12 Min.
Sitting quietly			30 sec.
Block 1	Task 1	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
	Task 2	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
	Task 3	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
	Task 4	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
Sitting quietly			1 min.
Administration of NASA TLX 1			6 min.
Sitting quietly			30 sec.
Block 2	Task 5	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
	Task 6	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
	Task 7	Baseline	30 sec.
		Instructions	20 sec.

Block 2	Task 7	Attention task	90 sec.
		Examination of task execution	90 sec.
	Task 8	Baseline	30 sec.
		Instructions	20 sec.
		Attention task	90 sec.
		Examination of task execution	90 sec.
Sitting quietly			1 min.
Administration of NASA TLX 2			6 min.

2.5 Recording of brain and cardiovascular activity

2.5.1 EEG recording

DC potentials were recorded using BIOSEMI soft- and hardware (ActiveTwo System). A 16-channel EEG was recorded using BioSemi Active pin-type sintered Ag-AgCl electrodes in conjunction with BioSemi headcaps, and BioSemi flat active sintered Ag-AgCl electrodes were used for external locations. BioSemi Active electrodes allow EEG recordings without skin preparation (i.e. puncturing) and are suitable for DC measurements.

The EEG was recorded from the following electrode positions: Fp1, Fp2, F3, Fz, F4, C3, Cz, C4, T7, T8, P3, Pz, P4, O1, Oz, O2 and referenced to CMS and DRL and re-referenced off-line to linked mastoids. Vertical EOG (above and below the left pupil) and skin potential (left index finger to forearm) were recorded as well.

Head circumference was measured in all participants and an appropriately sized headcap was selected. The headcaps' electrode holders were filled with SIGMA® electrolyte electrode gel and pin-type electrodes were mounted to the headcap. Flat electrodes for external positioning were applied with adhesive disks after preparing the skin with rubbing alcohol. EEG was digitalized at a sample rate of 512 Hz.

2.5.2 Cardiovascular recordings

ECG was recorded with a Holter monitor (Medilog® AR12, EVO Scientific Biosignal Recorder by TOM Medical Entwicklungs GmbH) with a channel 1 (V1-recording) and a channel 3 (skin potential) recording. However, only the V1-recording was analyzed for this thesis.

Subsequently to the EEG electrode application, ECG electrodes were applied after appropriate skin preparation. For the ECG electrodes were placed just below the right clavicle and below the left costal arch and referenced to an electrode placed in the middle of the sternum. Skin potential was measured as well with two electrodes, one at the tip of the left middle finger and one at the upper side of the left lower arm.

2.6 Data processing

2.6.1 EEG activity

EEG data were filtered, with high pass filter set to 30 Hz and low cut filter disabled, and exported with BESA (Brain Electrical Source Analysis, Version 5.2, MEGIS Software GmbH, Gräfelfing) and mean values for epochs of 1 second were calculated. DC potential changes were calculated for epochs of 270 seconds (a baseline of 30 seconds, 20 seconds of instruction, 90 seconds of attention task, 90 seconds of examination of task execution, and 30 seconds of the baseline for the following task). The first and last 60 seconds of each epoch were used to calculate the slope and eliminate it from the recorded segment for correction of DC drift artifacts (Hennighausen, Heil, & Rösler, 1993). DC potentials were visually inspected for artifacts and recordings of two persons were excluded. Mean values of three 30 second intervals for the attention tasks (50-79s, 80-109s, and 110-139s) were calculated in order to analyze DC potential shifts of the attention tasks over time.

2.6.2 Cardiovascular activity

ECG data were imported into Medilog Darwin analysis program (Schiller GmbH, Linz) and a template analysis was executed. Additionally a visual inspection was carried through. The spectrum of the HRV signal for intervals of 1 minute for the attention tasks (always the first 60 seconds of each attention task were selected) and intervals of 5 minutes for the baseline for the cardiovascular parameters (see Table 6) were calculated using the fast Fourier transform (FFT) algorithm by analyzing successive intervals of 128 sample points obtained over 5s epochs. The parameter values for the specified recording periods were exported into Microsoft Excel and checked for missing parameters.

2.7 Statistical analysis

Statistical analysis was performed with SPSS (Statistical Package for the Social Sciences, Version 17.0, SPSS Inc, Chicago, IL) and Statistica (Version 8.0, StatSoft Inc, Tulsa, OK). The verification of the normal distribution of variables was omitted due to the general robustness of the ANOVA to violations of the normality assumption (Maxwell, 2004).

An alpha level of .05 was applied for all statistical tests. In case of violation of sphericity the Huynh-Feldt corrections were used for estimates of sphericity greater than .75, and the Greenhouse-Geisser corrections were used for sphericity estimates less than .75 (Field, 2005).

Furthermore, effect sizes were calculated to illustrate the magnitude of the observed effect and to indicate its practical relevance.

2.8 Statistical hypotheses

In the following, only alternative hypotheses (H1) in regards to the formulated research questions will be reported without repeating the respective null-hypotheses (H0), stating that all differences in the data are due to chance.

2.8.1 Statistical hypothesis in regards to DC potentials

H1.1: The environmental rejection condition is associated with positive DC potential changes over the course of the attention task.

2.8.2 Statistical hypotheses in regards to heart rate

H1.2: The environmental intake condition produces heart rate deceleration compared to the baseline heart rate.

H1.3: The environmental rejection condition produces heart rate acceleration compared to the baseline heart rate.

2.8.3 Statistical hypotheses in regards to parameters of heart rate variability

H1.4: HRV, as measured by SDNN, has higher values in the environmental rejection condition than in the environmental intake condition.

H1.5: The LF power of HRV is higher in the environmental rejection condition than in the environmental intake condition.

3 Results

3.1 EEG activity

3.1.1 DC Potentials

H1.1: The environmental rejection condition is associated with positive DC potential changes over the course of the attention task.

In order to analyze the effect of the direction of attention on DC potential shifts a 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) x 3 (location: Fz, Cz, Pz) x 3 (time: 50-79s, 80-109s, 110-139s) repeated measures ANOVA was calculated. In case of significant effects, Bonferroni post hoc test was performed.

The grand means of the DC potential changes for each relevant location are shown for the entire block (230 seconds) over all 46 participants in Figure 5, Figure 6, and Figure 7.

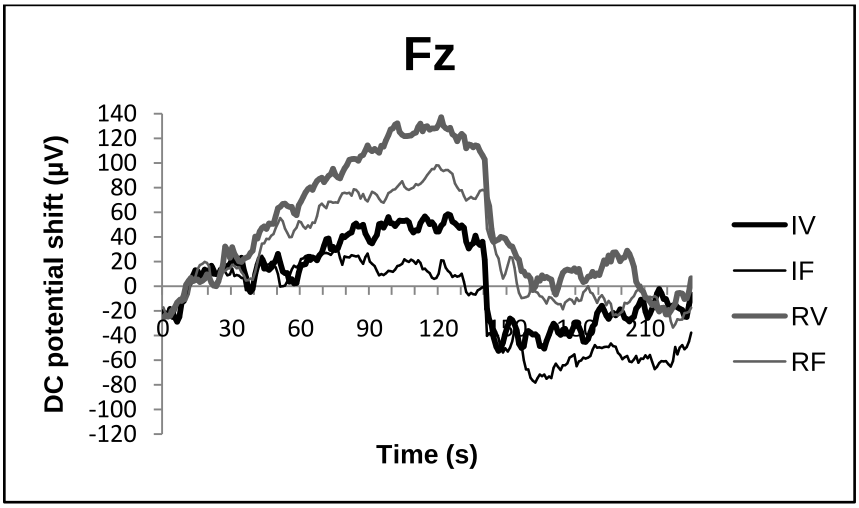

Figure 5. DC potential shifts at frontal (Fz) midline location for all four tasks: baseline (0-29s), instruction (30-49s), attention task (50-139s), and examination of task execution (140-229s).
Note. IV = verbal intake, IF = figural intake, RV = verbal rejection, and RF = figural rejection.

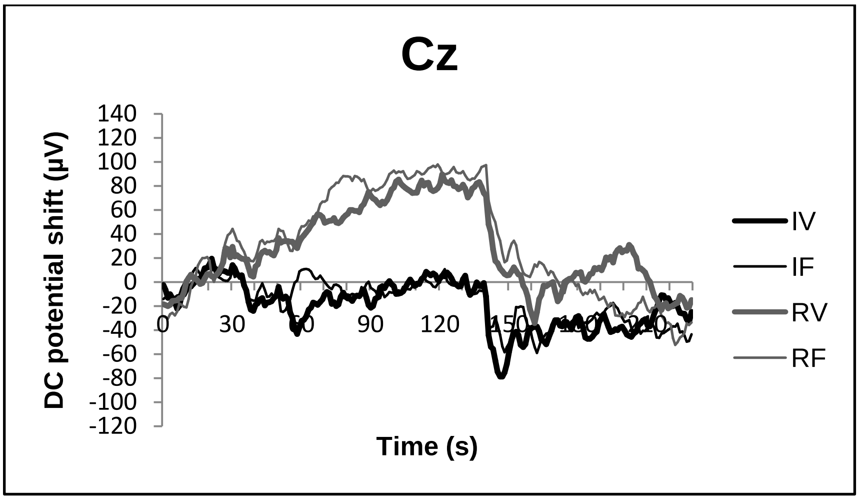

Figure 6. DC potential shifts at central (Cz) midline location for all four tasks: baseline (0-29s), instruction (30-49s), attention task (50-139s), and examination of task execution (140-229s). *Note.* IV = verbal intake, IF = figural intake, RV = verbal rejection, and RF = figural rejection.

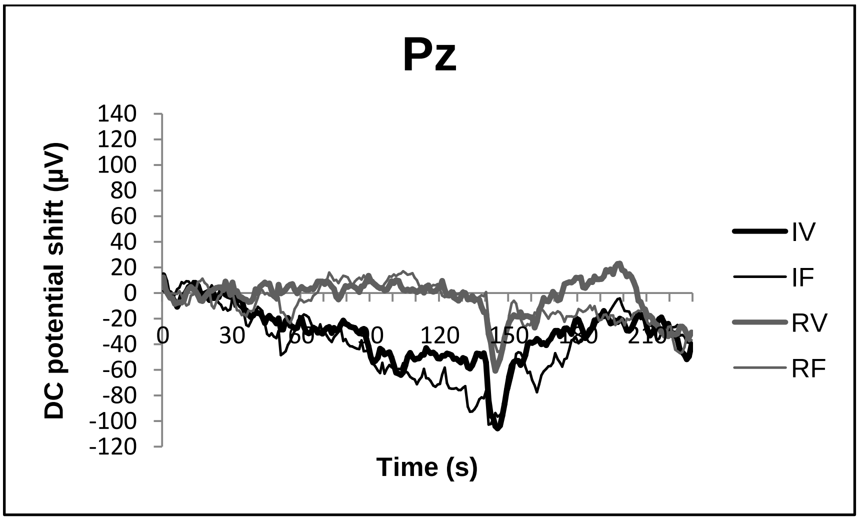

Figure 7. DC potential shifts at parietal (Pz) midline location for all four tasks: baseline (0-29s), instruction (30-49s), attention task (50-139s), and examination of task execution (140-229s). *Note.* IV = verbal intake, IF = figural intake, RV = verbal rejection, and RF = figural rejection.

Mauchly's test of sphericity indicated that the assumption of sphericity had been violated for the main effect of time, $\chi^2(2) = 23.42$, $p < .001$, and for the two-way interaction effects between location and time, $\chi^2(9) = 82.07$, $p < .001$, direction of attention and time, $\chi^2(2) = 34.08$, $p < .001$, modality and time, $\chi^2(2) = 36.58$, $p < .001$, and for the three-way interaction effects between location and direction of attention and modality, $\chi^2(2) = 7.49$, $p < .05$, location and direction of attention and time, $\chi^2(9) = 48.88$, $p < .001$, location and modality and time, $\chi^2(9) = 45.11$, $p < .001$, direction of attention and modality and time, $\chi^2(2) = 12.11$, $p < .01$, and for the four-way interaction effect between location and direction of attention and modality and time, $\chi^2(9) = 60.75$, *p*

< .001. Therefore, degrees of freedom were corrected using Huynh-Feldt (for the three-way interaction effects between location and direction of attention and modality, ε = .90, location and modality and time, ε = .76, and direction of attention and modality and time, ε = .83) and Greenhouse-Geisser (for the main effect of time, ε = .71, for the two-way interaction effects between location and time, ε = .67, direction of attention and time, ε = .65, modality and time, ε = .64, and for the three-way interaction effects between location and direction of attention and time, ε = .64, and for the four-way interaction effect between location and direction of attention and modality and time, ε = .68) estimates of sphericity. See Appendix B for Table B 29 for results of Mauchly's sphericity test.

Table 7 shows the results of the 4-way ANOVA for brain DC potential shifts.

Table 7. Results of 4-way ANOVA for brain DC potential shifts (µV) with repeated factors: direction of attention (intake, rejection), modality (verbal, figural), location (Fz, Cz, Pz), and time (50-79s, 80-109s, 110-139s).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η^2
direction of attention	1.00	1655332.95	45.00	276866.47	5.98	.018*	.117
modality	1.00	29588.44	45.00	99599.42	0.30	.588	.007
location	2.00	916724.43	90.00	42818.49	21.41	.000***	.322
time	1.42	22290.26	63.71	7748.27	2.88	.081	.060
direction of attention * modality	1.00	1757.70	45.00	58060.52	0.03	.863	.001
direction of attention * location	2.00	27077.50	90.00	14031.19	1.93	.151	.041
modality * location	2.00	48635.11	90.00	12666.42	3.84	.025*	.079
direction of attention * modality * location	1.79	5443.48	80.65	10082.98	0.54	.566	.012
direction of attention * time	1.30	49152.15	58.48	9870.12	4.98	.021*	.100
modality * time	1.28	11564.66	57.52	15024.33	0.77	.414	.017
direction of attention * modality * time	1.66	5002.36	74.84	5058.25	0.99	.364	.022
location * time	2.67	37378.24	120.33	2780.32	13.44	.000***	.230
direction of attention * location * time	2.56	1159.55	115.29	1339.42	0.87	.447	.019

Effect	df Effect	MS Effect	df Error	MS Error	F	Sig.	Part. η²
modality * location * time	3.02	2972.28	136.01	1210.81	2.45	.065	.052
direction of attention * modality * location * time	2.71	225.59	121.86	1195.10	0.19	.887	.004

Note. df = degrees of freedom, MS = Mean Square. *Indicates statistically significant effects *p* < .05, and ***indicates statistically significant effects *p* < .001.

There was a significant main effect of direction of attention *F* (1, 45) = 5.98, *p* < 0.05, partial η^2 = .12 (see Figure 8), indicating that independent of time, location, and modality DC potential changes differed between the environmental intake and environmental rejection condition with positive DC potential shifts in the rejection condition and negative DC potential shifts in the intake condition.

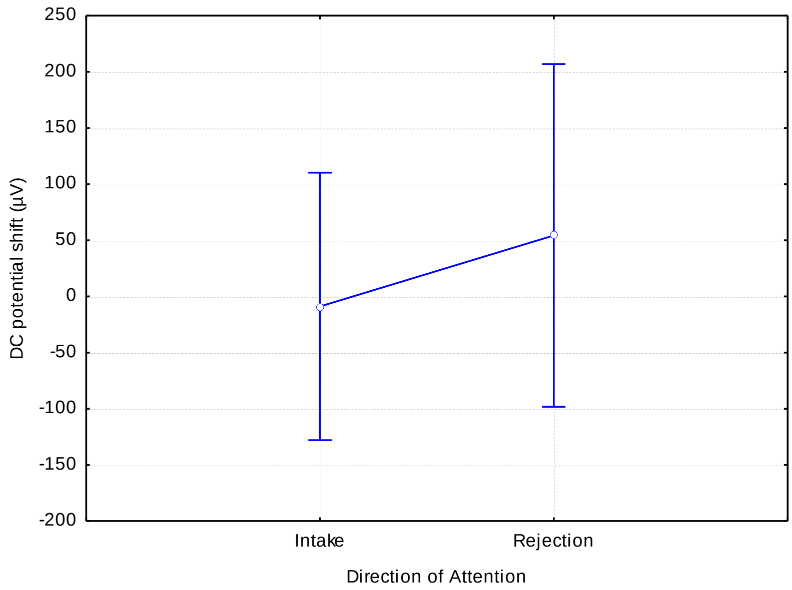

Figure 8. Main effect of direction of attention for DC potential shifts (µV), *F* (1, 45) = 5.98, *p* < .05. Vertical bars denote .95 confidence intervals.

Furthermore, there was a significant main effect of location, *F* (2, 90) = 21.41, *p* < .001, partial η^2 = .32 (see Figure 9), indicating that independent of time, direction of attention, and modality DC potential shifts differed between frontal, central, and parietal midline locations. Bonferroni post hoc test revealed significant differences in DC potential shifts between frontal and parietal midline locations, *p* < .001, and between central and parietal midline locations, *p* < .001 (see Appendix B for Table B 30).

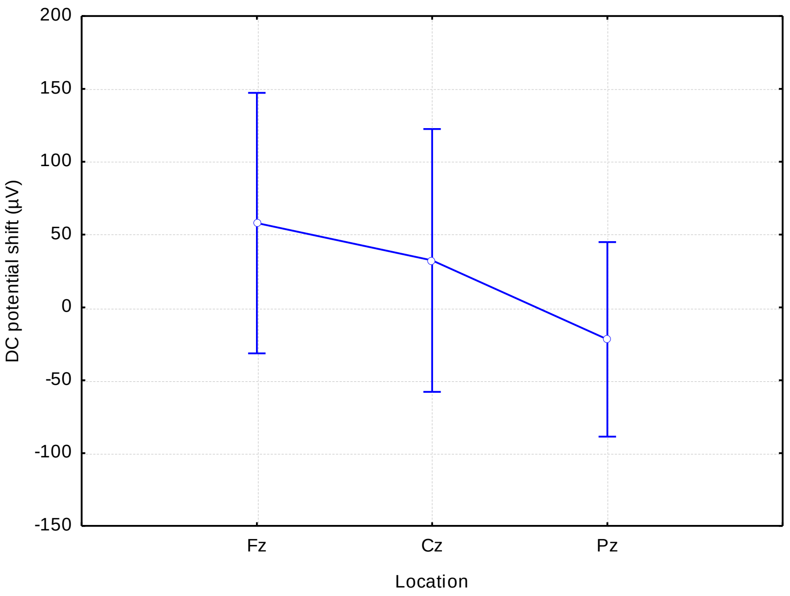

Figure 9. Main effect of location for DC potential shifts (µV), F (2, 90) = 21.41, p < 0.001. Vertical bars denote .95 confidence intervals.

There were no significant main effects of modality, *F* (1, 45) = 0.30, *ns* (see Figure 10) and of time, *F* (1.42, 63.71) = 2.88, *ns* (see Figure 11).

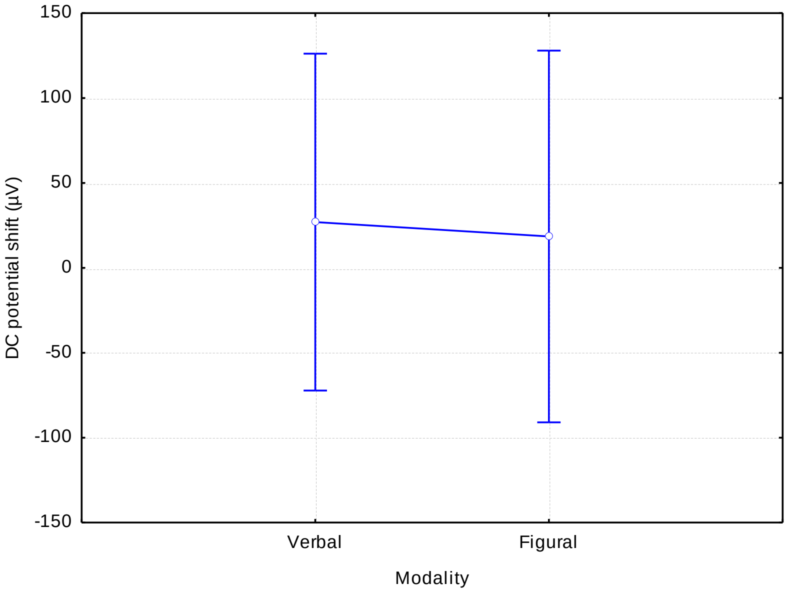

Figure 10. Main effect of modality for DC potential shifts (µV), *F* (1, 45) = .30, *ns*. Vertical bars denote .05 confidence intervals.

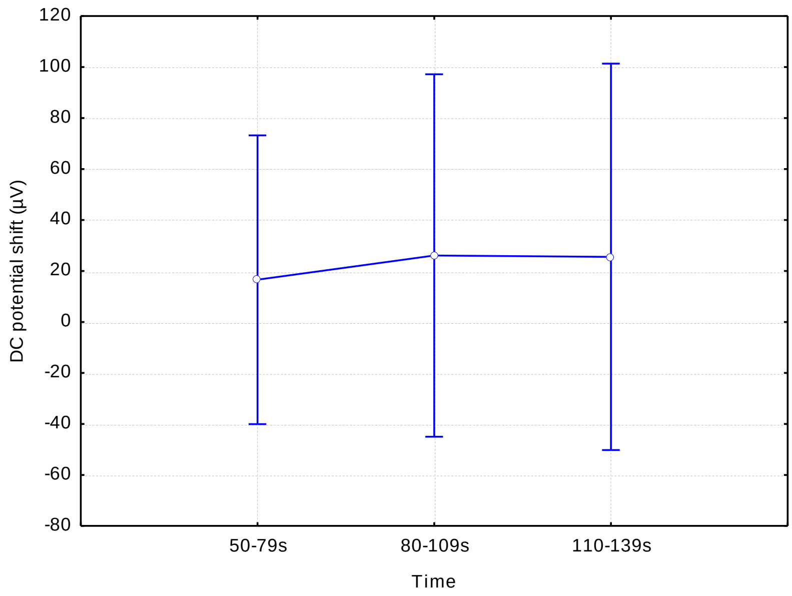

Figure 11. Main effect of time for DC potential shifts (µV), F (1.42, 63.71) = 2.88, *ns*. Vertical bars denote .05 confidence intervals.

However, there was a significant interaction effect between direction of attention and time, F (1.3, 58.48) = 4.98, $p < .05$, partial $\eta^2 = .10$. This indicates that over the course of the attention task DC potential changes differed between the environmental intake and the environmental rejection condition and within the respective conditions. To break down this interaction a post-hoc test using the Bonferroni adjustment was performed (see Appendix B for Table B 31).

This revealed significant differences in the environmental rejection condition between the times 50-79s and 80-109s, $p < .05$, and between the times 50-79s and 110-139s, $p < .05$. Furthermore, significant differences were shown between the environmental intake and environmental rejection condition at all times, all $p < .001$, indicating that DC potential shifts differed from 50-79s to 80-109s to 110-139s depending on the direction of attention condition.

Looking at the interaction graph (see Figure 12) this means that surface positivity increased significantly over the course of the attention tasks in the environmental rejection condition, but surface negativity remained relatively stable in the environmental intake condition.

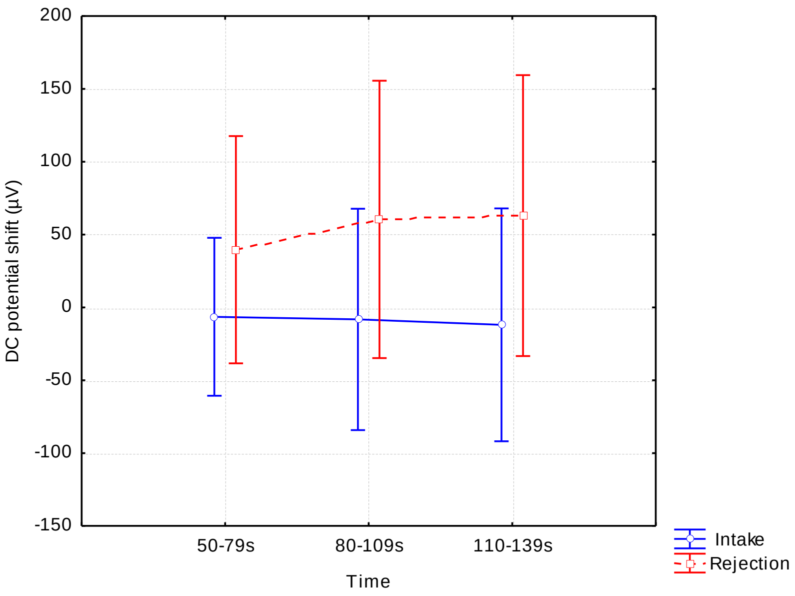

Figure 12. Interaction effect between direction of attention x time for DC potential shifts (µV), *F* (1.3, 58.48) = 4.98, $p < .05$. Vertical bars denote .95 confidence intervals.

There also was a significant interaction effect between location and time, *F* (2.67, 120.33) = 13.44, $p < .001$, partial $\eta^2 = .23$. Bonferroni post hoc test revealed significant differences at the frontal midline location between the times 50-79s and 80-109s, $p < .01$, and between the times 50-79s and 110-139s, $p < .001$, at the central midline location between the times 50-79s and 80-109s, $p < .05$, and between the times 50-79s and 110-139s, $p < .001$, and at the parietal midline location between the times 50-79s and 110-139s, $p < .01$. Furthermore, significant differences were shown between central and parietal midline locations at all times, all $p < .001$, and between frontal and parietal midline locations at all times, all $p < .001$. The Bonferroni post hoc test also indicated the following significant differences between frontal and central midline locations: at 50-79s, 80-109s, and 110-139s and between 50-79s and 80-109s and between 80-109s and 110-139s (see Appendix B for Table B 32).

DC potential shifts (see Figure 13) significantly increased in positivity at the frontal midline location and at the central midline location between 50-79s and 80-109s and remained about the same between 80-109s and 110-139s and significantly decreased in negativity between 50-79s and 110-139s at the parietal midline location. These effects therefore reflect negative DC potential shifts over the course of the attention tasks at the parietal midline location, compared to positive DC potential shifts over the course of the attention tasks at the frontal and central midline locations.

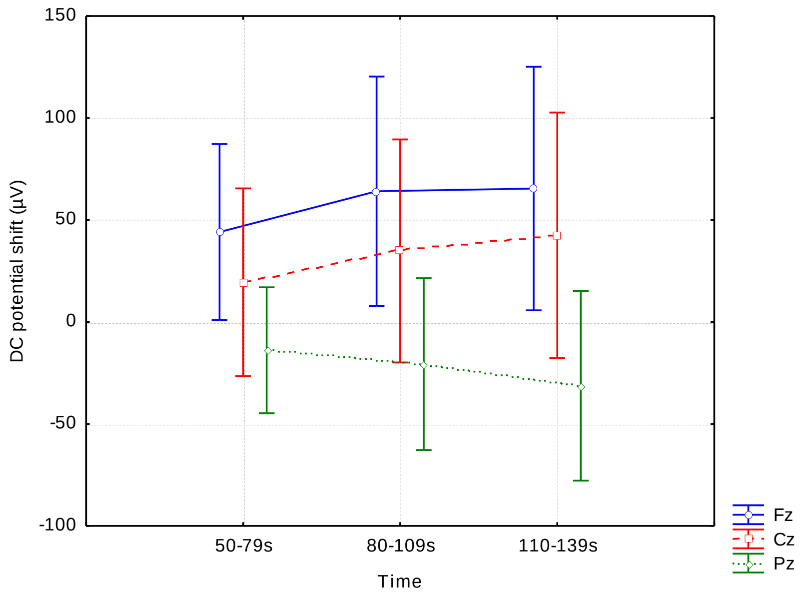

Figure 13. Interaction effect between location x time for DC potential shifts (µV) *F* (2.67, 120.33) = 13.44, *p* < .001. Vertical bars denote .95 confidence intervals.

In addition, the modality and location interaction was significant, *F* (2, 90) = 3.84, *p* < .05, partial η^2 = .08, indicating that the type of modality had different effects on DC potential shifts at frontal, central and parietal midline locations. Bonferroni post hoc test revealed a significant interaction in the verbal condition between all midline locations, all *p* < .001, and in the figural condition between frontal and parietal midline locations, *p* < .001, and between central and parietal midline locations, *p* < .001. Furthermore, a significant interaction between the verbal and figural condition was shown between frontal and central midline locations, *p* < .01, between frontal and parietal midline locations, *p* < .001, and between central and parietal locations, *p* < .001 (see Appendix B for Table B 33).

In the verbal and figural condition (see Figure 14) DC potential changes were positive at frontal and central locations, but negative at parietal midline locations. In the verbal condition DC potential shifts differed significantly between frontal, central, and parietal midline locations, whereas in the figural condition DC potential shifts only differed significantly between the frontal and parietal midline locations and between the central and parietal midline locations. Moreover, there was a more positive DC potential shift in the verbal condition (compared to the figural condition) at the frontal midline location compared to the central midline location, where DC potentials were slightly less positive in the verbal condition compared to the figural condition. Additionally, the difference in DC potential shifts in the verbal condition compared to the figural condition is greater at the central midline location compared to the parietal midline location with a more positive DC potential shift in the verbal condition and a negative DC potential shift in both conditions at the parietal midline location. Furthermore, the difference in DC potential shifts in the verbal condition compared to the figural condition is greater at the frontal midline location compared to the parietal midline location.

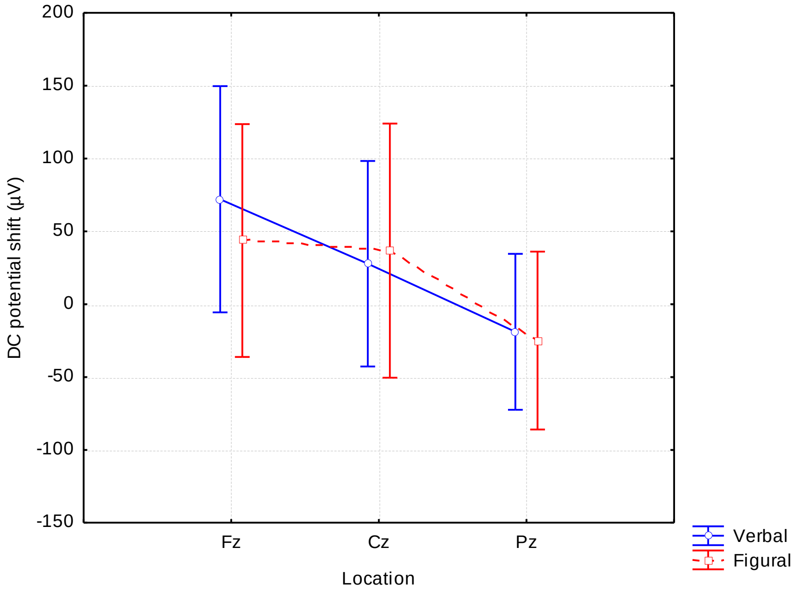

Figure 14. Interaction effect between location x modality for DC potential shifts (µV), F (2, 90) = 3.84,
p < .05. Vertical bars denote .95 confidence intervals.

There were no significant interaction effects between location and direction of attention, F (2, 90) = 1.93, *ns* (see Figure 15), between direction of attention and modality, F (1, 45) = .03, *ns* (see Figure 16), and between modality and time, F (1.28, 57.52) = .77, *ns* (see Figure 17).

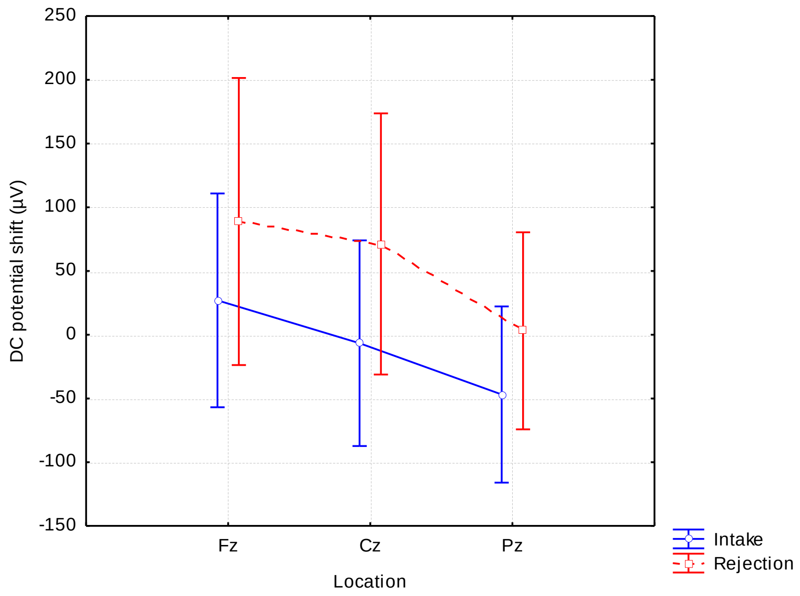

Figure 15. Interaction effect between location x direction of attention for DC potential shifts (µV), *F* (2, 90) = 1.93, *ns*. Vertical bars denote .95 confidence intervals.

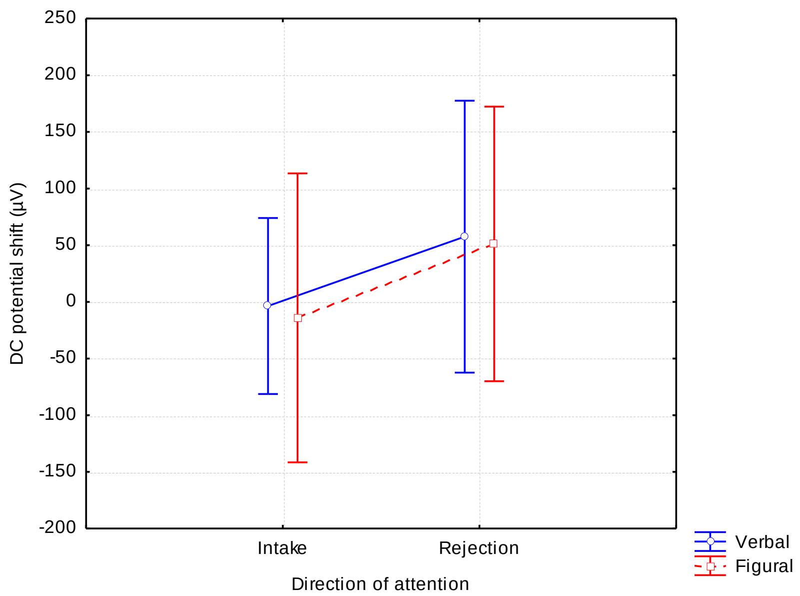

Figure 16. Interaction effect between direction of attention x modality for DC potential shifts (µV), *F* (1, 45) = .03, *ns*. Vertical bars denote .95 confidence intervals.

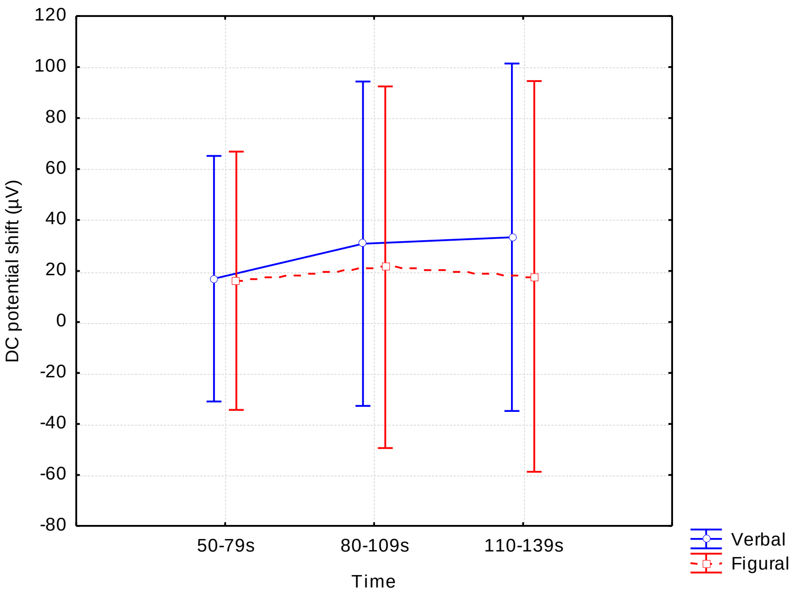

Figure 17. Interaction effect between modality x time for DC potential shifts (µV), *F* (1.28, 57.52) = .77, *ns*. Vertical bars denote .95 confidence intervals.

Furthermore, there were no significant interaction effects between location and direction of attention and modality, *F* (1.79, 80.65) = .54, *ns* (see Figure 18), between location and direction of attention and time, *F* (2.56, 115.29) = .87, *ns* (see Figure 19), between location and modality and time, *F* (3.02, 136.01) = 2.45, *ns* (see Figure 20), and between direction of attention and modality and time, *F* (1.66, 74.84) = .99, *ns* (see Figure 21).

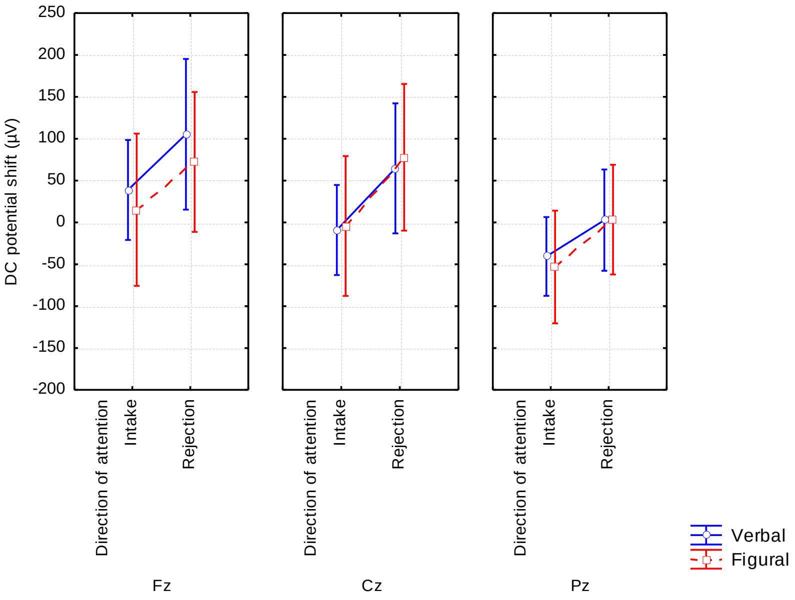

Figure 18. Interaction effect between location x direction of attention x modality for DC potential shifts (µV), *F* (1.79, 80.65) = .54, *ns*. Vertical bars denote .95 confidence intervals.

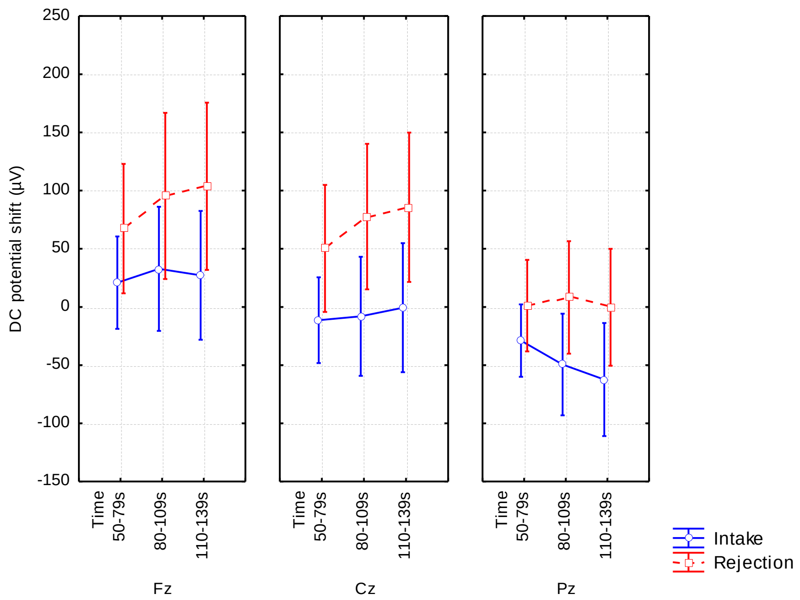

Figure 19. Interaction effect between location x direction of attention x time for DC potential shifts (µV), *F* (2.56, 115.29) = .87, *ns*. Vertical bars denote .95 confidence intervals.

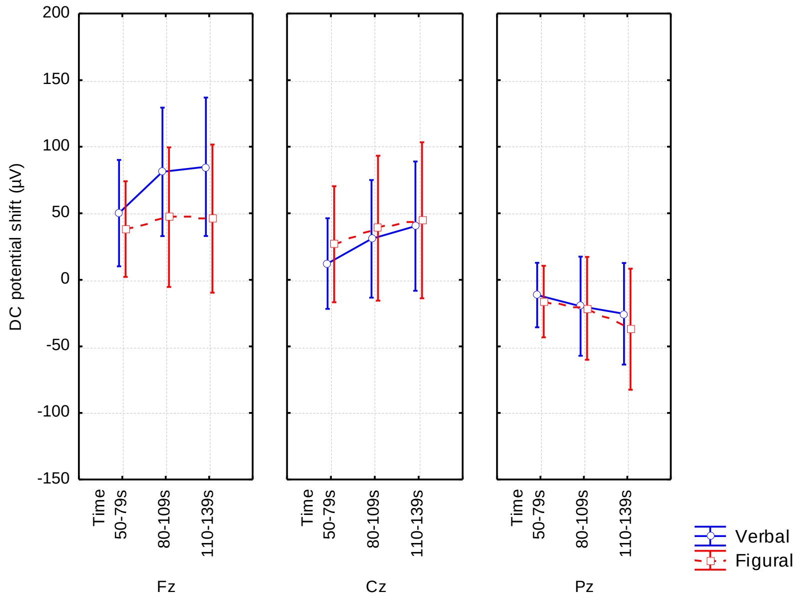

Figure 20. Interaction effect between location x modality x time for DC potential shifts (µV), *F* (3.02, 136.01) = 2.45, *ns*. Vertical bars denote .95 confidence intervals.

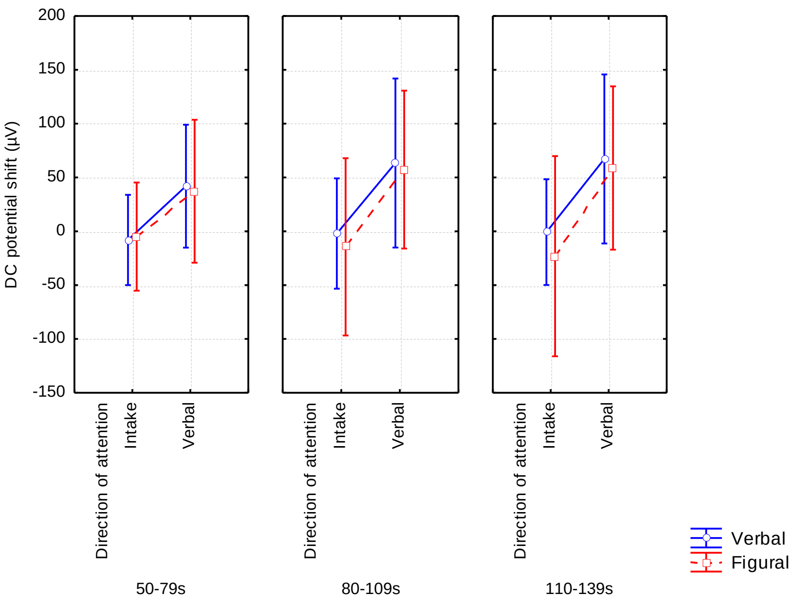

Figure 21. Interaction effect between direction of attention x modality x time for DC potential shifts (µV), *F* (1.66, 74.84) = .99, *ns*. Vertical bars denote .95 confidence intervals.

Moreover, there was no significant interaction effect between location and direction of attention and modality and time, *F* (2.71, 121.86) = .19, *ns* (see Figure 22, Figure 23, and Figure 24).

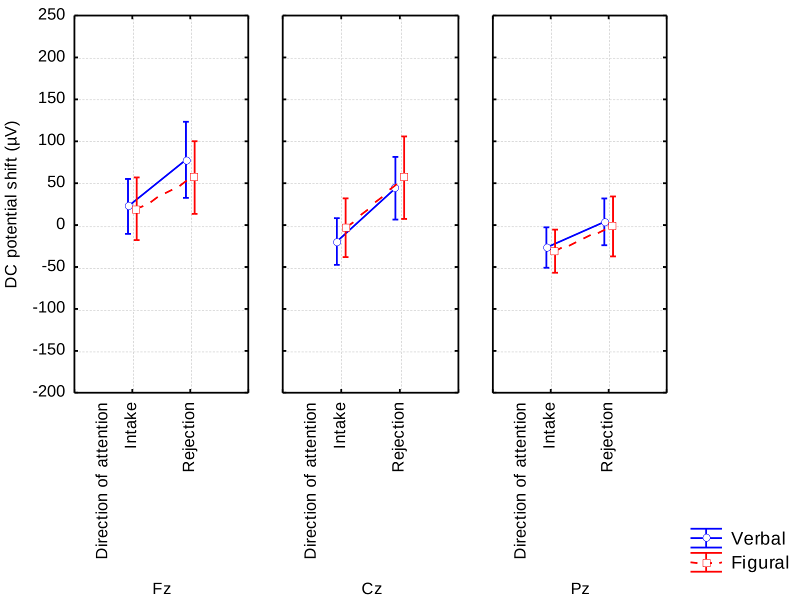

Figure 22. Interaction effect between location x direction of attention x modality x time with factor level time: 50-79s for DC potential shifts (µV), *F* (2.71, 121.86) = .19, *ns*. Vertical bars denote .95 confidence intervals.

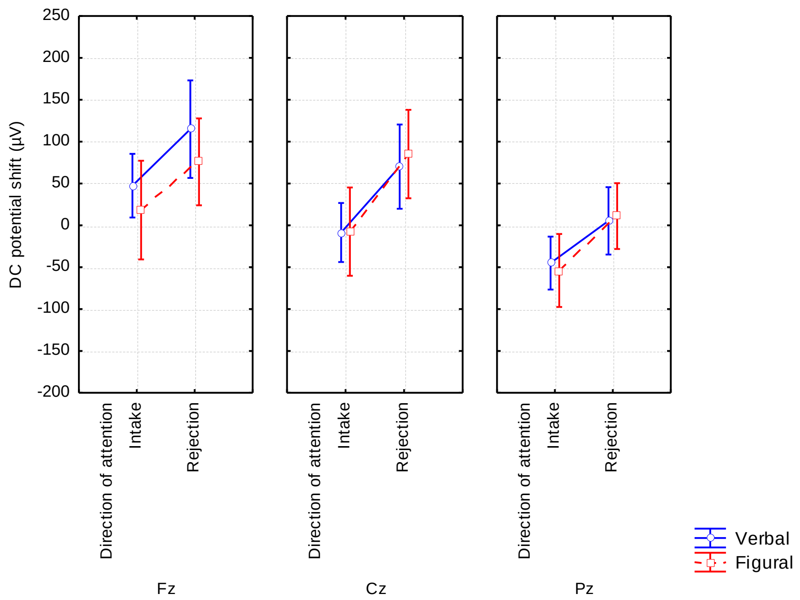

Figure 23. Interaction effect between location x direction of attention x modality x time with factor level time: 80-109s for DC potential shifts (µV), *F* (2.71, 121.86) = .19, *ns*. Vertical bars denote .95 confidence intervals.

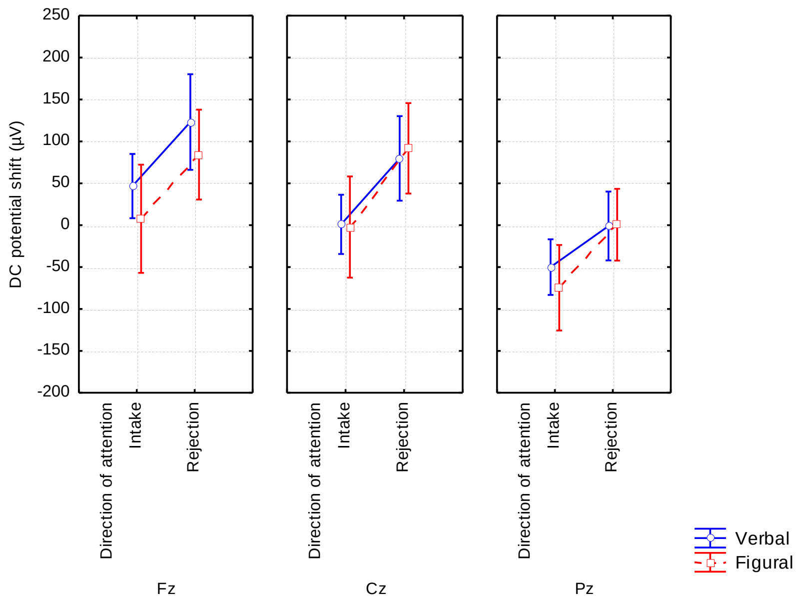

Figure 24. Interaction effect between location x direction of attention x modality x time with factor level time: 110-139s for DC potential shifts (µV), *F* (2.71, 121.86) = .19, *ns*. Vertical bars denote .95 confidence intervals.

3.1.2 Further analysis

In order to verify that the significant findings for DC potential shifts are a result of the applied experimental manipulation, vertical EOG and skin potential (SP) were analyzed as well.

3.1.2.1 Vertical EOG

A 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) x 3 (time: 50-79s, 80-109s, 110-139s) repeated measures ANOVA was calculated for vertical EOG. In case of significant effects, Bonferroni post hoc test was performed.

Mauchly's test of sphericity indicated that the assumption of sphericity had been violated for the main effect of time, $\chi^2(2) = 30.08$, $p < .00$, for the two-way interaction effect between direction of attention and time, $\chi^2(2) = 10.77$, $p < .01$, and for the three-way interaction effect between direction of attention and modality and time, $\chi^2(2) = 18.52$, $p < .001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser (for the main effect of time, ε = .67 and for the interaction effect between direction of attention and modality and time, ε = .74) and Huynh-Feldt (for the interaction effect between direction of attention and time, ε = .85) estimates of sphericity. See Appendix B for Table B 34 for results of Mauchly's sphericity test.

Table 8 shows the results of the three-way ANOVA for vertical EOG.

Table 8. Results of 3-way ANOVA for vertical EOG (µV) with repeated factors: direction of attention (intake, rejection), modality (figural, verbal), and time (50-79s, 80-109s, 110-139s).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η²
direction of attention	1.00	23077.08	45.00	60633.72	0.38	.540	.008
modality	1.00	26413.78	45.00	80901.26	0.33	.571	.007
Time	1.34	11216.06	60.19	10607.43	1.06	.329	.023
direction of attention * modality	1.00	9835.55	45.00	36622.85	0.27	.607	.006
direction of attention * time	1.70	31144.42	76.38	5320.78	5.85	.007**	.115
modality * time	2.00	1319.72	90.00	3610.92	0.37	.695	.008
direction of attention * modality * time	1.49	6073.48	66.99	6106.06	0.99	.354	.022

Note. df = degrees of freedom, MS = Mean Square. **Indicates statistically significant effects $p < .01$.

There was a significant interaction effect between direction of attention and time, $F = (1.7, 76.38) = 5.85$, $p < .01$, partial $\eta^2 = .12$, for the vertical EOG. Bonferroni post hoc test revealed significant differences in the intake condition between the times 50-79s and 80-109s, $p < .05$. Moreover, a significant difference was detected between the intake and the rejection condition between the times 80-109s and 110-139s, $p < .001$, indicating that the vertical EOG differed from 80-109s to 110-130s depending on the direction of attention condition (see Figure 25 and Appendix B for Table B 35).

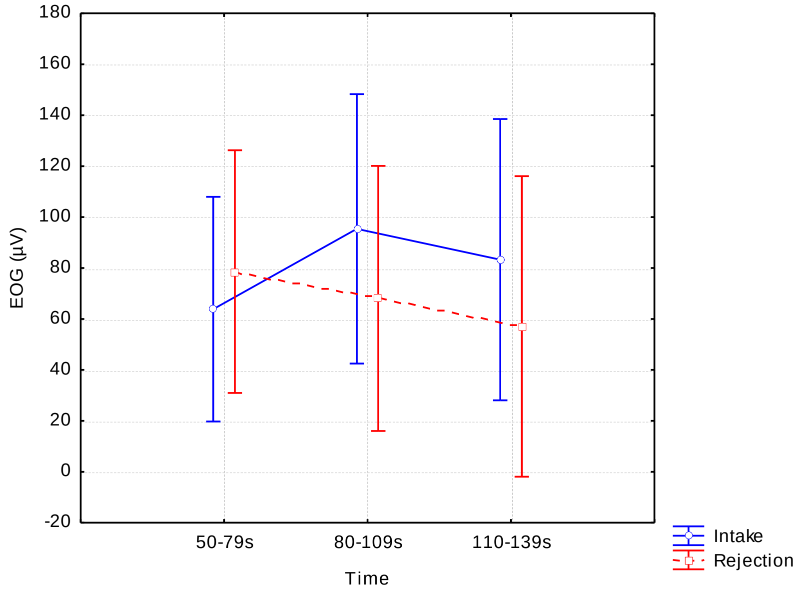

Figure 25. Interaction effect between direction of attention x time for vertical EOG (µV), F (1.69, 73.94) = 5.85, $p < .01$. Vertical bars denote .95 confidence intervals.

3.1.2.2 Skin potential

A 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) x 3 (time: 50-79s, 80-109s, 110-139s) repeated measures ANOVA was calculated for the skin potential. In case of significant effects, Bonferroni post hoc test was performed.

Mauchly's test of sphericity indicated that the assumption of sphericity had been violated for the main effect of time, $\chi^2(2) = 82.63$, $p < .001$, for the two-way interaction effect between direction of attention and time, $\chi^2(2) = 9.43$, $p < .01$, between modality and time $\chi^2(2) = 14.93$, p < .01, and for the three-way interaction effect between direction of attention and modality and time, $\chi^2(2) = 18.51$, $p < .001$. Therefore degrees of freedom were corrected using Greenhouse-Geisser (for the main effect of time, ε = .54) and Huynh-Feldt (for the interaction effect between direction of attention and time, ε = .87, between modality and time, ε = .80, and between attention and modality and time, ε = .76) estimates of sphericity. See Appendix B for Table B 36 for results of Mauchly's sphericity test.

See Table 9 for results of three-way ANOVA of skin potential.

Table 9. Results of 3-way ANOVA for skin potential (µV) with repeated factors: direction of attention (intake, rejection), modality (figural, verbal), and time (50-79s, 80-109s, 110-139s).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η^2
direction of attention	1.00	1361313.69	45.00	2624246.21	0.52	.475	.011
modality	1.00	2650822.02	45.00	2885961.92	0.92	.343	.020
time	1.08	696609.10	48.72	1751949.65	0.40	.548	.009
direction of attention * modality	1.00	1290827.06	45.00	2739231.61	0.47	.496	.010
direction of attention * time	1.73	407220.06	78.03	119883.22	3.40	.045*	.070
modality * time	1.60	852829.09	71.93	170492.57	5.00	.014*	.100
direction of attention * modality * time	1.53	3579216.97	68.76	229853.36	15.57	.000***	.257

Note. df = degrees of freedom, MS = Mean Square. ***Indicates statistically significant effects $p < .001$, *indicates statistically significant effects $p < .05$.

There was a significant interaction effect between direction of attention and time, $F = (1.73, 78.03) = 3.40$, $p < .05$, partial $\eta^2 = .07$. Bonferroni post hoc test (see Appendix B for Table B 37) revealed a significant difference in the rejection condition between the times 50-79s and 110-139s, $p < .05$. Moreover, a significant difference was detected between the intake and the rejection condition at 50-79s, $p < .01$ and between the times 50-79s and 80-109s, $p < .05$, and between 50-79s and 110-139s $p < .01$, indicating that the skin potential differed from 50-79s to 80-109s and from 50-79s to 110-139s depending on the direction of attention condition (see Figure 26).

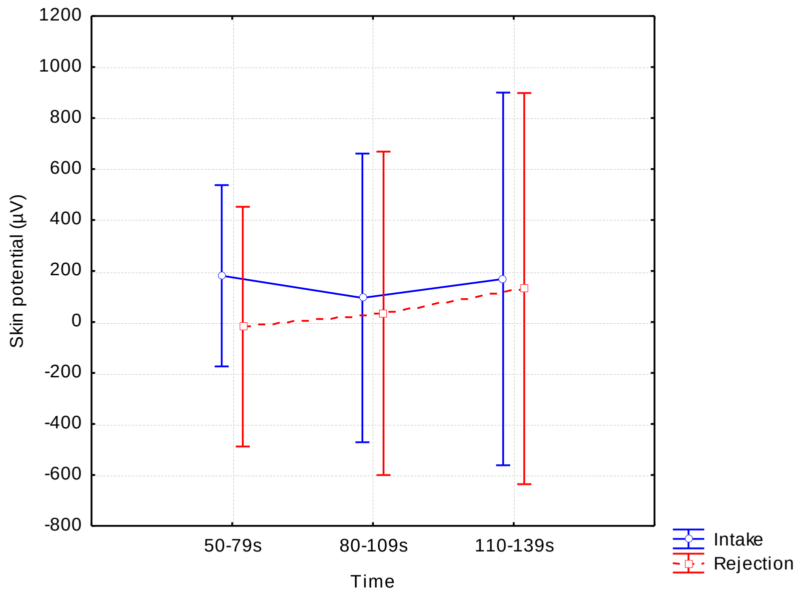

Figure 26. Interaction effect between direction of attention x time for skin potential (µV), F = (1.73, 78.03) = 3.40, p < .05. Vertical bars denote .95 confidence intervals.

Furthermore, there was a significant interaction effect between modality and time, F = (1.60, 71.93) = 5.00, p < .05, partial η^2 = .10 (see Figure 27). Bonferroni post hoc test (see Appendix B for Table B 38) revealed a significant difference between the verbal and the figural condition at 50-79s and at 80-109s, p < .05, p < .01, and between 50-79s and 80-109s, p < .001, and 50-79s and 110-139s, p < .01.

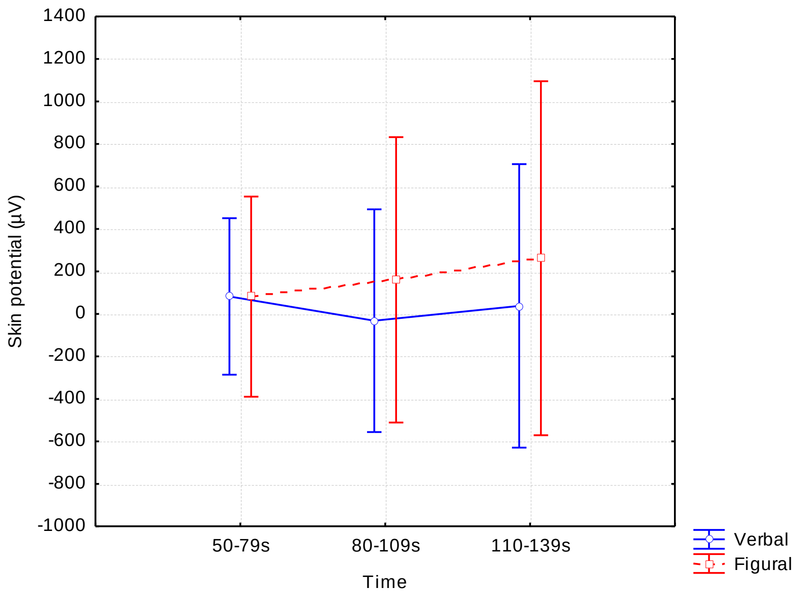

Figure 27. Interaction effect between modality x time for skin potential (µV), F = (1.60, 71.93) = 5.00, p < .05. Vertical bars denote .95 confidence intervals.

Moreover, a significant interaction effect between direction of attention and modality and time, $F = (1.53, 68.76) = 15.57$, $p < .001$ partial $\eta^2 = .26$, was detected (see Figure 28). See Appendix B for Table B 38 for results of Bonferroni post hoc test.

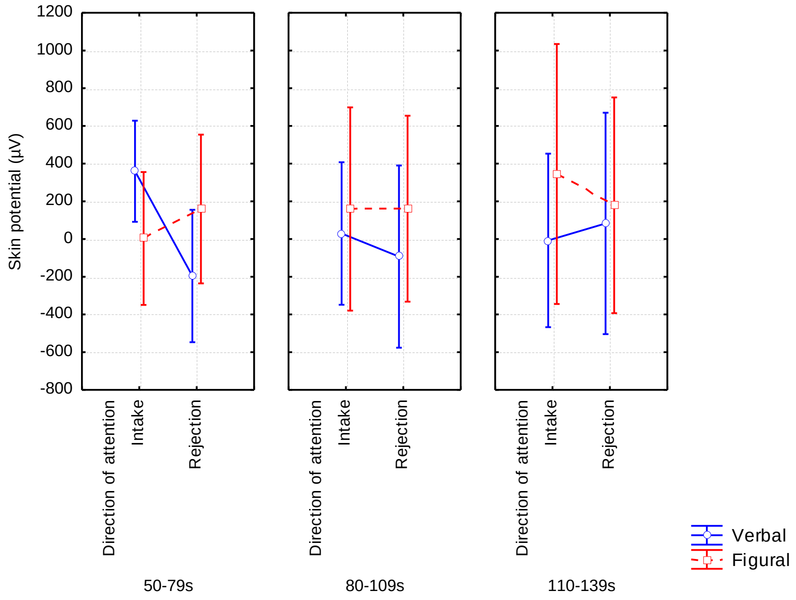

Figure 28. Interaction effect between direction of attention x modality x time for skin potential (µV), $F = (1.53, 68.76) = 15.57$, $p < .001$. Vertical bars denote .95 confidence intervals.

3.1.3 Summary of results

It was hypothesized that the environmental rejection condition is associated with positive DC potential changes over the course of the attention task. Moreover, the effects of the direction of attention were examined in verbal and figural takes, in order to take account for modality effects on the direction of attention.

Looking at the results of the 4-way repeated measures ANOVA for brain DC potential shifts it can be concluded that the environmental rejection condition is indeed associated with positive DC potential changes, compared to the environmental intake condition which is associated with a negative DC potential shift. Figure 12 shows the increasing positive DC potential shifts in the environmental rejection condition, compared to relatively stable negative DC potential shifts in the environmental intake condition. This effect is independent of location. Furthermore, it could be determined that the direction of attention is not subject to modality effects. Even though control recordings of vertical EOG and skin potential indicated a significant interaction effect of direction of attention and time for both vertical EOG and skin potential, vertical EOG and skin potential changed differently over the course of the intake and rejection attention tasks compared to brain DC potentials shifts (see Appendix B for Table B 21). Thus, the experimental hypothesis can be accepted.

3.2 Cardiovascular activity

3.2.1 Heart rate

H1.2: The environmental intake condition produces heart rate deceleration compared to the baseline heart rate.

In order to analyze the effect of the environmental intake condition (verbal as well as figural) on heart rate compared to the baseline heart rate a one-way repeated measures ANOVA (condition: baseline, intake-verbal, intake-figural) was calculated. In case of significant effects, Bonferroni post hoc test was performed.

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 14.07$, $p < .01$. Therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity ($\varepsilon = .81$) (see Appendix B for Table B 40).

The results from the one-way repeated measures ANOVA (see Table 10) showed that heart rate in the intake condition (verbal as well as figural) did not significantly differ from the baseline heart rate, F (1.62, 72.77) = 1.76, *ns*. Thus, the null-hypothesis cannot be rejected.

Table 10. Results of one-way ANOVA for heart rate (mean BpM) with repeated factor condition (baseline, intake-verbal, intake-figural).

Effect	df Effect	MS Effect	df Error	MS Error	F	Sig.	Part. η²
condition	1.62	42.98	72.77	24.37	1.76	.184	.038

Note. df = degrees of freedom, MS = Mean Square.

See Figure 29 for a graph of the main effect of condition.

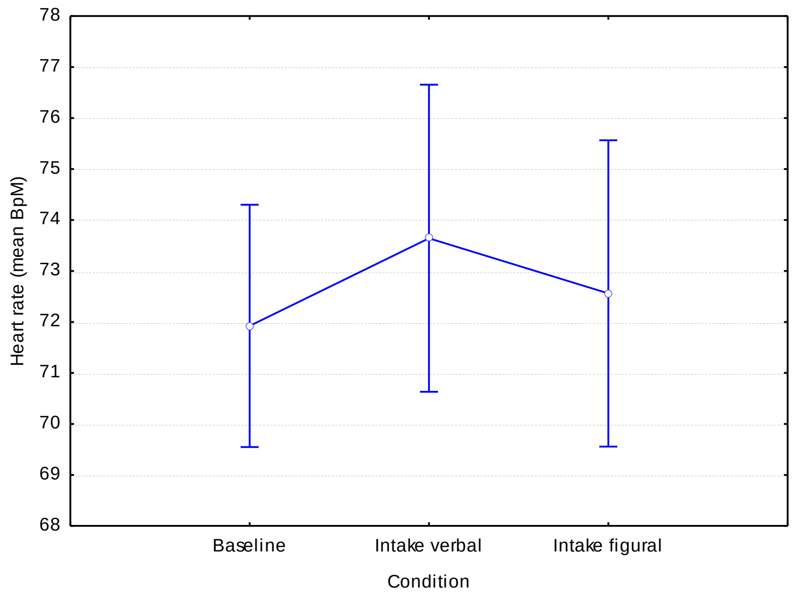

Figure 29. Main effect of condition (baseline, intake-verbal, intake-figural) for heart rate (mean BpM), F (1.62, 72.77) = 1.76, ns. Vertical bars denote .05 confidence intervals.

H1.3: The environmental rejection condition produces heart rate acceleration compared to the baseline heart rate.

In order to analyze the effect of the environmental rejection condition (verbal as well as figural) on heart rate compared to the baseline heart rate a one-way repeated measures ANOVA (condition: baseline, rejection-verbal, rejection-figural) was calculated. In case of significant effects, Bonferroni post hoc test was performed.

Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 9.16$, $p < .05$. Therefore, degrees of freedom were corrected using Huynh-Feldt estimates of sphericity (ε = .87) (see Appendix B for Table B 41).

The results from the one-way repeated measures ANOVA (see Table 11) showed that heart rate in the rejection condition (verbal as well as figural) did not significantly differ from the baseline heart rate, *F* (1.74, 78.38) = 1.38, *ns*. Thus, the null-hypothesis cannot be rejected.

Table 11. Results of one-way ANOVA for heart rate (mean BpM) with repeated factor condition (baseline, rejection-verbal, rejection-figural).

Effect	df Effect	MS Effect	df Error	MS Error	F	Sig.	Part. η²
condition	1.74	24.49	78.38	17.78	1.38	.257	.043

Note. df = degrees of freedom, MS = Mean Square.

See Figure 30 for a graph of the main effect of condition.

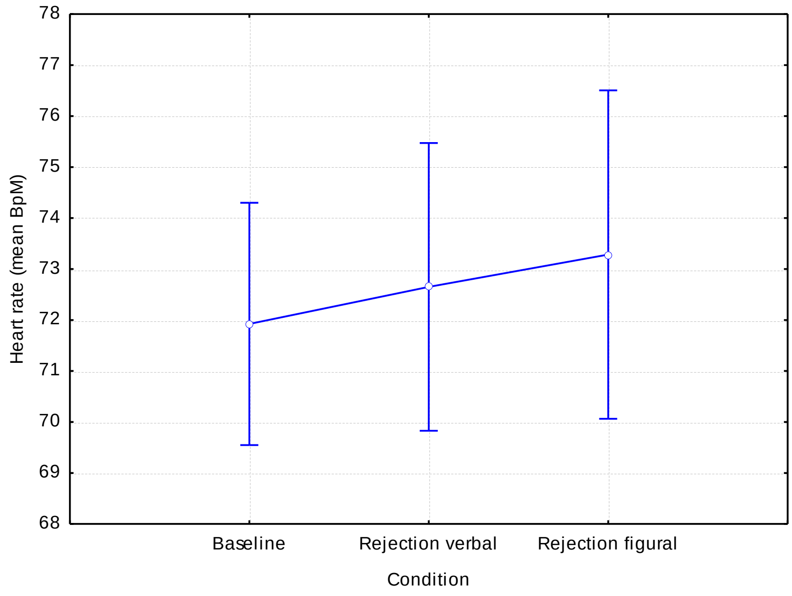

Figure 30. Main effect of condition (baseline, rejection-verbal, rejection-figural) for heart rate (mean BpM), *F* (1.74, 78.38) = 1.38, *ns*. Vertical bars denote .95 confidence intervals.

3.2.2 Time domain measures of HRV

3.2.2.1 SDNN

H1.4: HRV, as measured by SDNN, has higher values in the environmental rejection condition than in the environmental intake condition.

In order to analyze the effect of the direction of attention on SDNN a 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) repeated measures ANOVA was calculated. In case of significant effects, Bonferroni post hoc test was performed.

See Table 12 for the results of the two-way ANOVA for SDNN.

Table 12. Results of 2-way ANOVA for SDNN (ms) with repeated factors: direction of attention (intake, rejection) and modality (verbal, figural).

Effect	df Effect	MS Effect	df Error	MS Error	F	Sig.	Part. η^2
direction of attention	1	163.98	45	83.37	1.97	.168	.042
modality	1	299.37	45	162.49	1.84	.181	.039
direction of attention * modality	1	131.41	45	115.483	1.14	.292	.025

Note. df = degrees of freedom, MS = Mean Square.

There were no significant main effects of direction of attention, *F* (1, 45) = 1.97, *ns*, or of modality, *F* (1, 45) = 1.84, *ns*. Furthermore, the interaction effect between direction of attention and modality was not significant, *F* = (1, 45) = 1.14, *ns*.

This indicates that SDNN did not have higher values in the environmental rejection condition than in the environmental intake condition. Thus, the null-hypothesis cannot be rejected.

See Figure 31, Figure 32, and Figure 33 for graphs of the main effect of direction of attention and modality and the interaction effect between direction of attention and modality for SDNN.

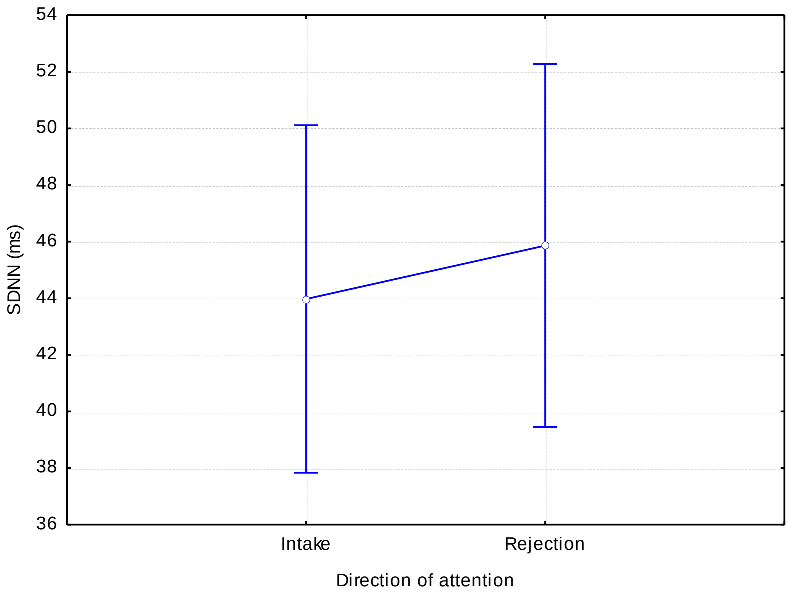

Figure 31. Main effect of direction of attention for SDNN (ms), *F* (1, 45) = 1.97, *ns*. Vertical bars denote .95 confidence intervals.

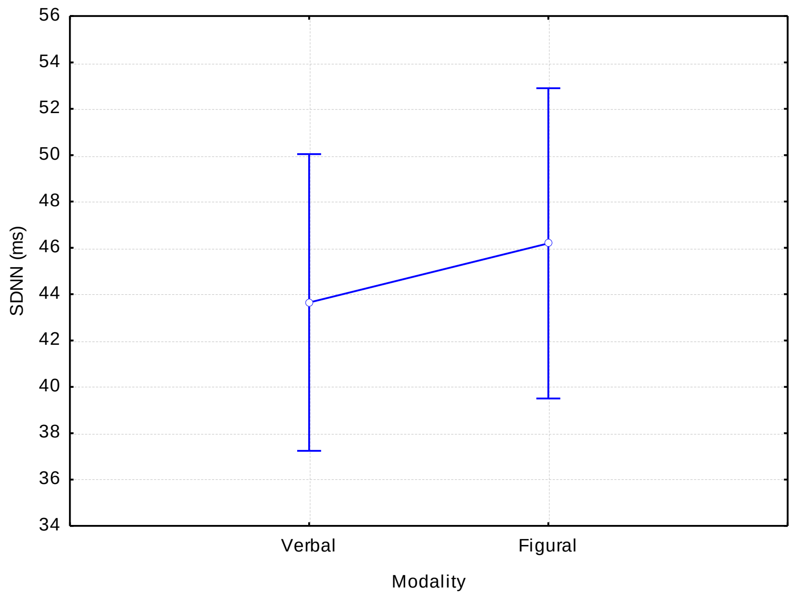

Figure 32. Main effect of modality for SDNN (ms), *F* (1, 45) = 1.84, *ns*. Vertical bars denote .95 confidence intervals.

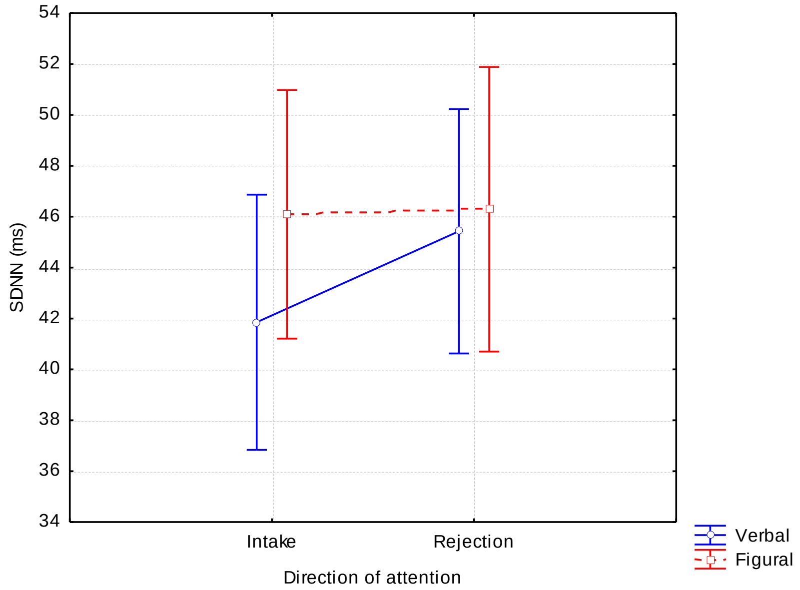

Figure 33. Interaction effect between direction of attention x modality for SDNN (ms), *F* (1, 45) = 1.14, *ns*. Vertical bars denote .95 confidence intervals.

3.2.2.2 Further analysis

Due to the lack of previous research on the effects of the direction of attention on time domain measures of heart rate variability, the effects of environmental intake versus environmental rejection on the following parameters will be illustrated as well: RMSSD and pNN50.

To analyze the effect of the direction of attention on RMSSD and pNN50, a 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) repeated measures ANOVA was calculated. In case of significant effects, Bonferroni post hoc test was performed.

- RMSSD

Table 13 shows the results of the two-way ANOVA for RMSSD with the repeated factors direction of attention and modality.

Table 13. Results of 2-way ANOVA for RMSSD (ms) with repeated factors: direction of attention (intake, rejection) and modality (verbal, figural).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η^2
direction of attention	1	185.80	45	101.00	1.84	.182	.039
modality	1	234.90	45	141.70	1.66	.204	.036
direction of attention * modality	1	132.77	45	123.00	1.08	.304	.023

Note. df = degrees of freedom, MS = Mean Square.

No significant main effects of direction of attention, F (1, 45) = 1.84, *ns*, or of modality, F = (1, 45) = 1.66, *ns*, could be illustrated. Moreover, the interaction effect between direction of attention and modality was not significant, F (1, 45) = 1.08, *ns*.

This indicates that RMSSD did not differ significantly between the environmental intake and environmental rejection condition.

See Figure 34, Figure 35, and Figure 36 for graphs of the main effect of direction of attention and the main effect of modality as well as the interaction effect between direction of attention and modality for RMSSD.

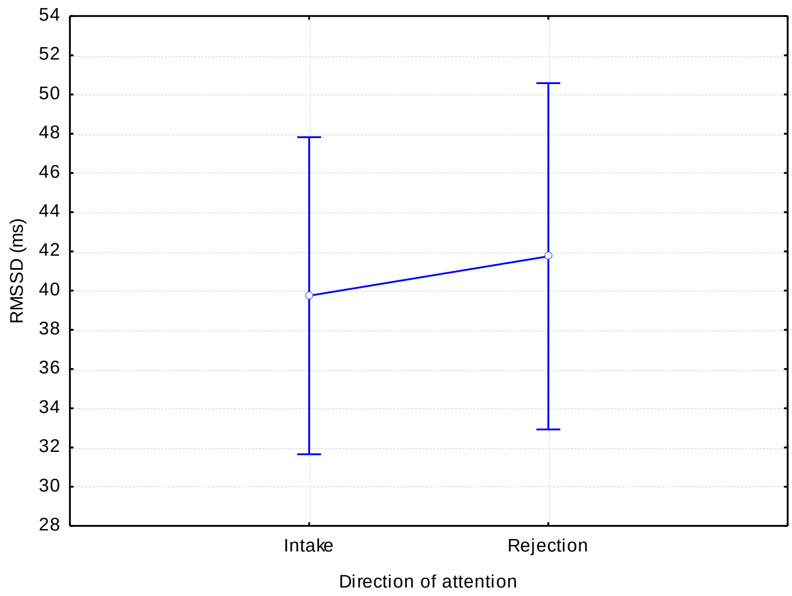

Figure 34. Main effect of direction of attention for RMSSD (ms), *F* (1, 45) = 1.84, *ns*. Vertical bars denote .95 confidence intervals.

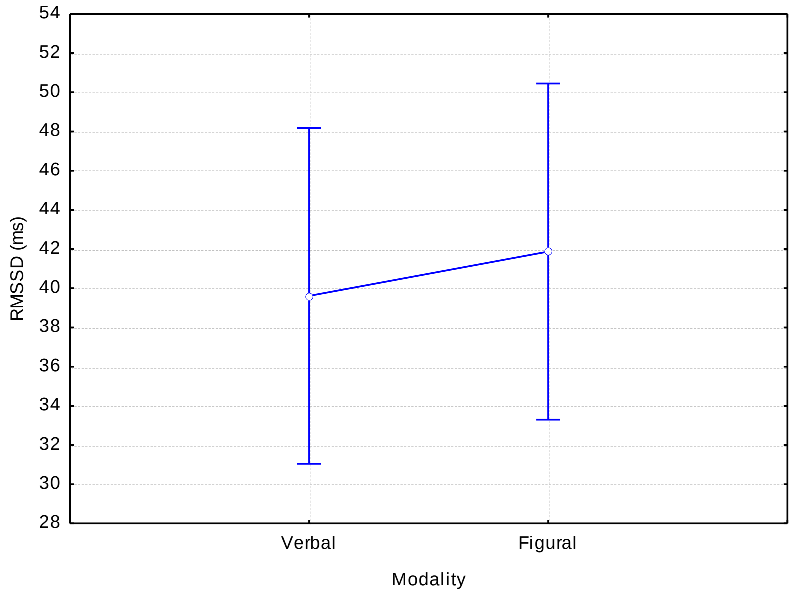

Figure 35. Main effect of modality for RMSSD (ms), *F* = (1, 45) = 1.66, *ns*. Vertical bars denote .95 confidence intervals.

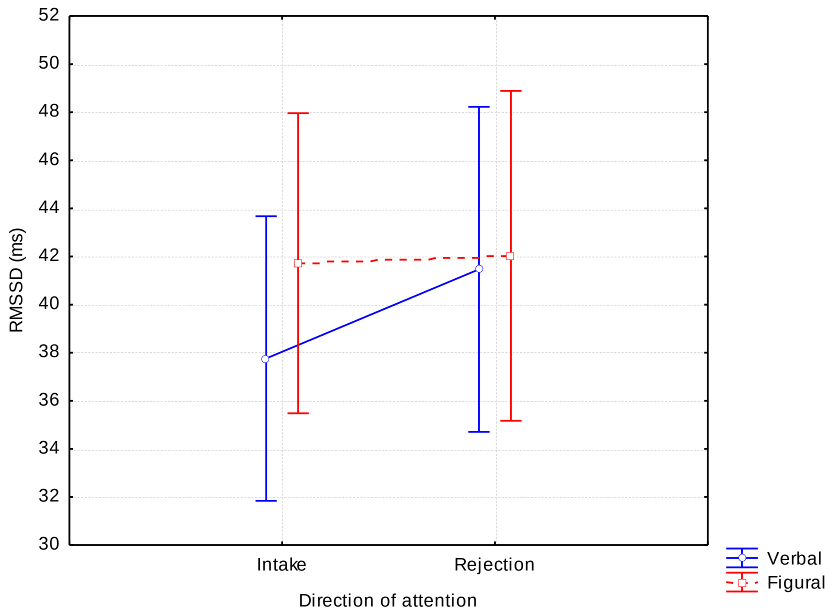

Figure 36. Interaction effect between direction of attention x modality for RMSSD (ms), F (1, 45) = 1.08, *ns*. Vertical bars denote .95 confidence intervals.

- pNN50

See Table 14 for the results of the two-way repeated measures ANOVA (factors: direction of attention and modality) for pNN50.

Table 14. Results of 2-way ANOVA for pNN50 (%) with repeated factors: direction of attention (intake, rejection) and modality (verbal, figural).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η^2
direction of attention	1	61.79	45	91.76	.67	.416	.015
modality	1	202.42	45	128.29	1.58	.216	.034
direction of attention * modality	1	12.68	45	111.97	.11	.738	.003

Note. df = degrees of freedom, MS = Mean Square.

There were no significant main effects of direction of attention, F (1, 45) = .67, *ns*, or of modality, F (1, 45) = 1.58, *ns*. In addition, no significant interaction effect between direction of attention and modality, F (1, 45) = .11, *ns*, could be demonstrated.

This indicates that pNN50 did not differ significantly between the environmental intake and environmental rejection condition.

See Figure 37, Figure 38, and Figure 39 for graphs of the main effects of direction of attention and modality and the interaction effect between direction of attention and modality for pNN50.

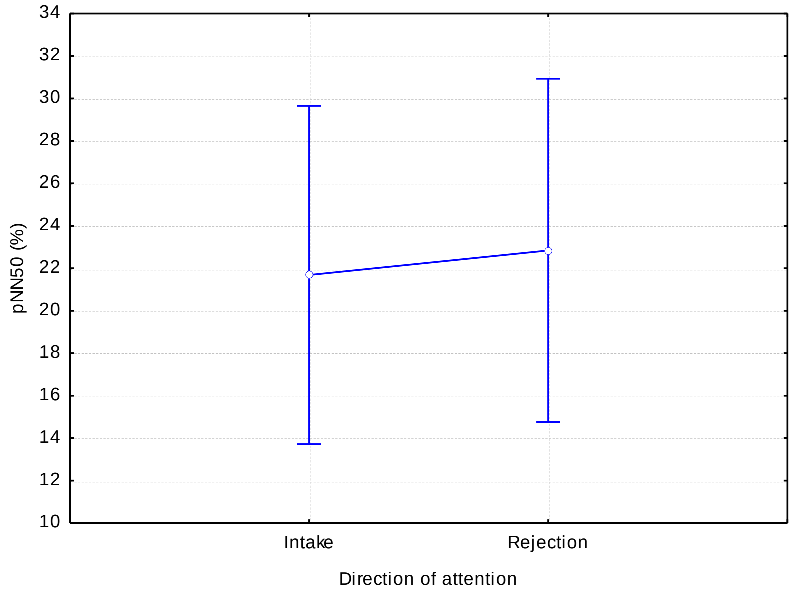

Figure 37. Main effect of direction of attention for pNN50 (%), *F* (1, 45) = .67, *ns*. Vertical bars denote .95 confidence intervals.

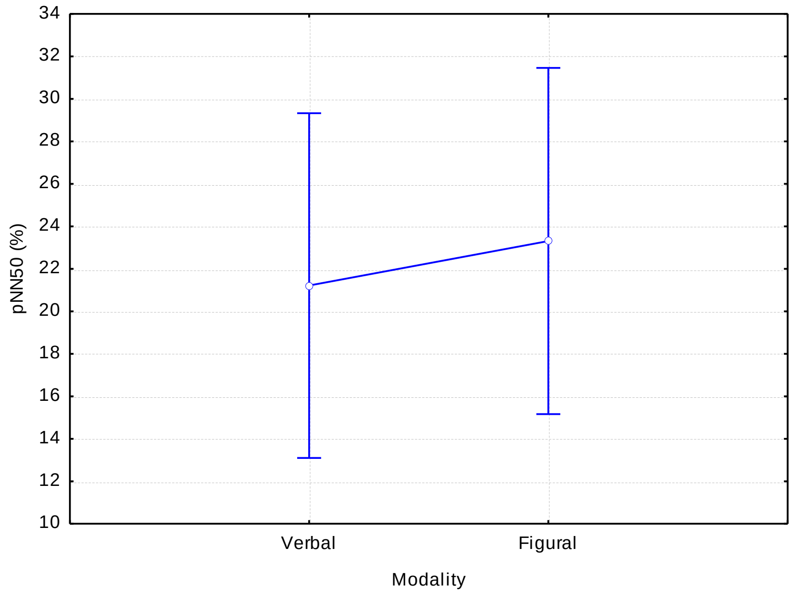

Figure 38. Main effect of modality for pNN50 (%), *F* (1, 45) = 1.58, *ns*. Vertical bars denote .95 confidence intervals.

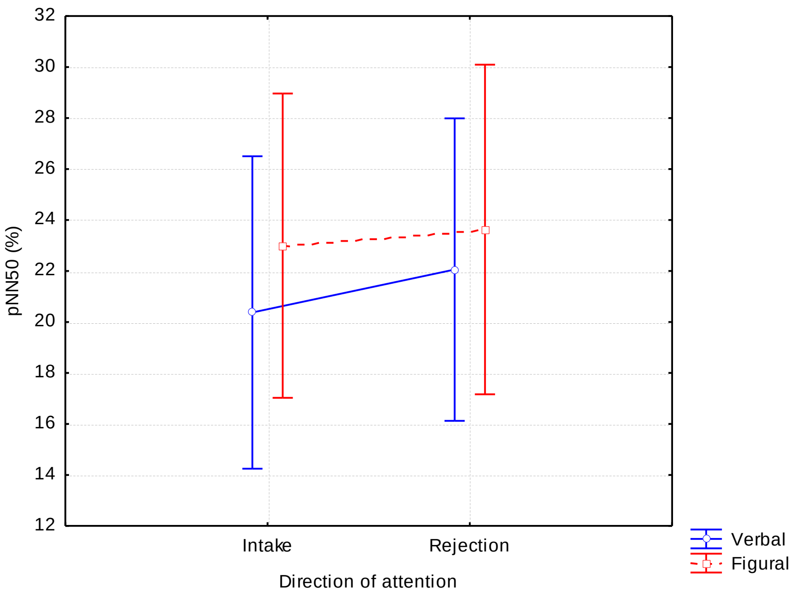

Figure 39. Interaction effect between direction of attention x modality for pNN50 (%), *F* (1, 45) = .11, *ns*. Vertical bars denote .95 confidence intervals.

3.2.3 Frequency domain measures of HRV

3.2.3.1 LF

H1.5: The LF power of HRV is higher in the environmental rejection condition than in the environmental intake condition.

In order to analyze the effect of the direction of attention on LF power a 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) repeated measures ANOVA was calculated. In case of significant effects, Bonferroni post hoc test was performed.

See Table 15 for the results of the two-way repeated measures ANOVA for LF.

Table 15. Results of 2-way ANOVA for LF (ms^2) with repeated factors: direction of attention (intake, rejection) and modality (verbal, figural).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η^2
direction of attention	1	143635.07	45	189505.71	.76	.389	.017
modality	1	279326.06	45	480621.27	.58	.450	.013
direction of attention * modality	1	262309.66	45	228453.85	1.15	.290	.025

Note. df = degrees of freedom, MS = Mean Square.

There was no significant main effect of direction of attention, *F* (1, 45) = .76, *ns*. Furthermore, a significant main effect of modality could not be detected, *F* (1, 45) = .58, *ns*. Additionally, the interaction effect between attention and modality was not significant, *F* = (1, 45) = 1.15, *ns*.

These results indicate that the LF power of HRV was not higher in the environmental rejection condition than the environmental intake condition. Thus, the null-hypothesis cannot be rejected.

See Figure 40, Figure 41, and Figure 42 for graphs of the main effects of direction of attention and modality and the interaction effect between direction of attention and modality for LF.

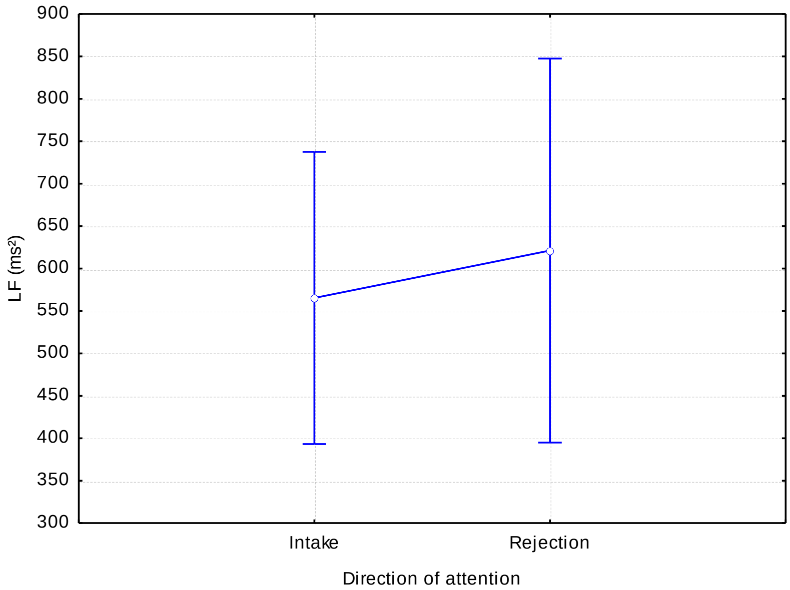

Figure 40. Main effect of direction of attention for LF (ms²), *F* (1, 45) = .76, *ns*. Vertical bars denote .95 confidence intervals.

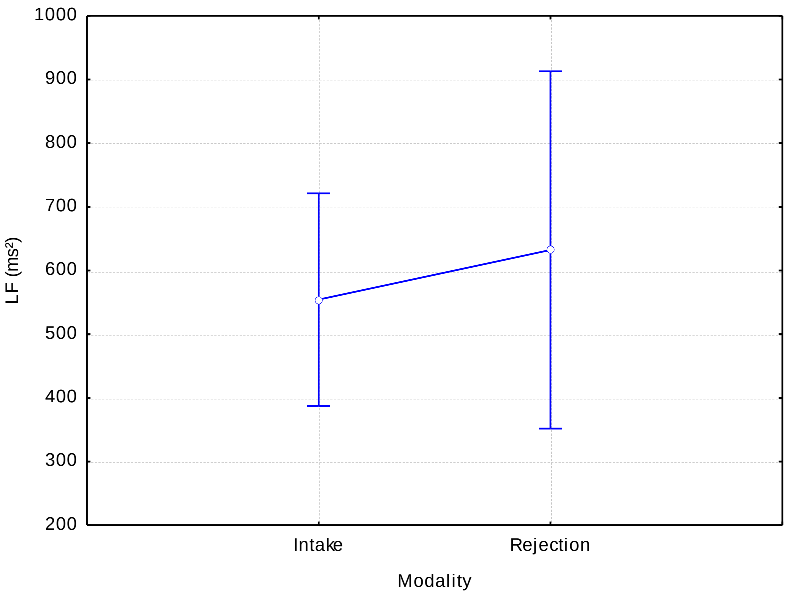

Figure 41. Main effect of modality for LF (ms²), *F* (1, 45) = .58, *ns*. Vertical bars denote .95 confidence intervals.

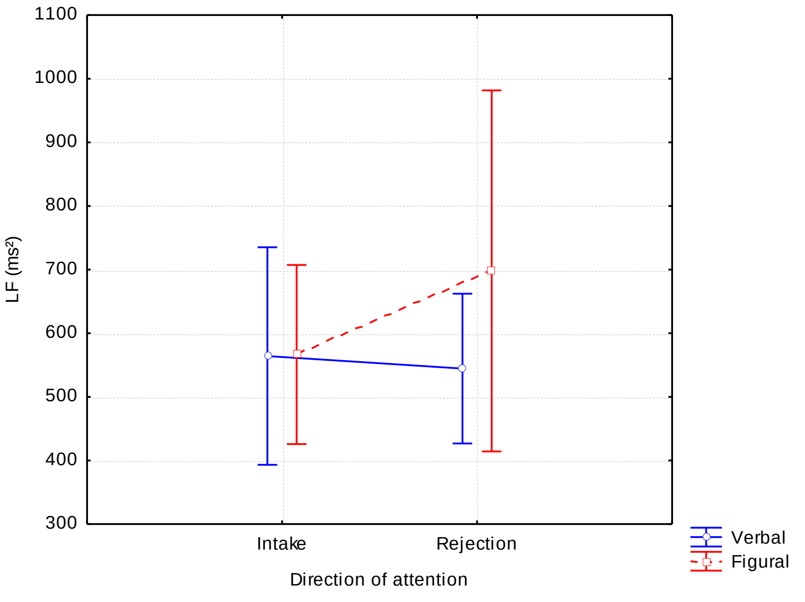

Figure 42. Interaction effect between direction of attention x modality for LF (ms²), *F* (1, 45) = 1.15, *ns*. Vertical bars denote .95 confidence intervals.

3.2.3.2 Further analysis

Effects of attention directed towards the internal environment compared to attention directed towards the external environment on frequency domain measures have hardly been studied so far. Therefore the effects of environmental intake versus environmental rejection on the following frequency domain parameters will be illustrated as well: total power, HF power.

To analyze the effect of the direction of attention on total power and HF power, a 2 (direction of attention: intake, rejection) x 2 (modality: verbal, figural) repeated measures ANOVA was calculated. In case of significant effects, Bonferroni post hoc test was performed.

- Total power

Table 16 indicates the results of the two-way ANOVA for total power with repeated factors direction of attention and modality.

Table 16. Results of 2-way ANOVA for total power (ms^2) with repeated factors: direction of attention (intake, rejection) and modality (verbal, figural).

	df	MS	df	MS			
Effect	Effect	Effect	Error	Error	F	Sig.	Part. η^2
direction of attention	1	2636033.41	45	888153.19	2.97	.092	.062
modality	1	2962556.66	45	1551277.09	1.91	.174	.041
direction of attention * modality	1	538013.81	45	903844.51	0.60	.444	.013

Note. df = degrees of freedom, MS = Mean Square.

There were no significant main effects of direction of attention, F (1, 45) = 2.97, *ns*, and of modality, F (1, 45) = 1.91, *ns*. Moreover, a significant interaction effect between direction of attention and modality, F (1, 45) = .60, *ns*, could not be illustrated.

This therefore indicates that total power did not differ significantly between the environmental intake and environmental rejection condition.

See Figure 43, Figure 44, and Figure 45 for graphs of the main effects of direction of attention and modality and the interaction effect between direction of attention and modality for total power.

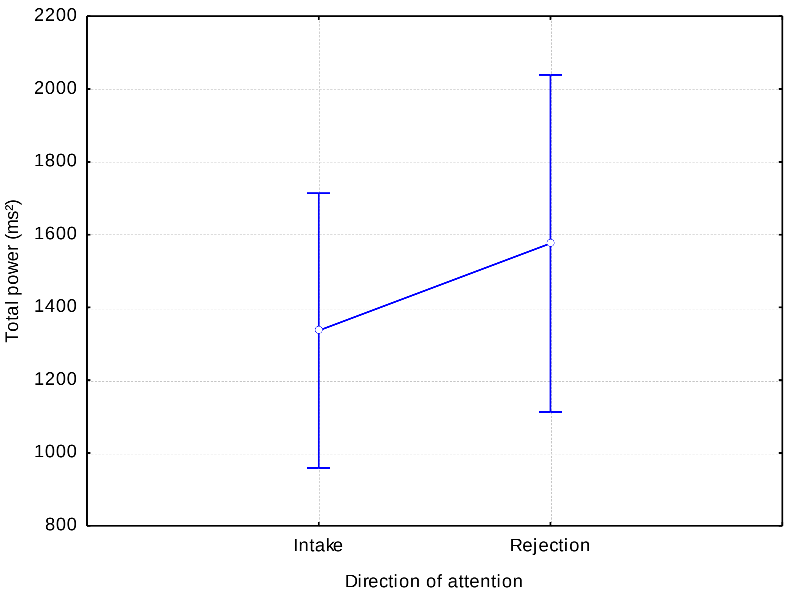

Figure 43. Main effect of direction of attention for total power (ms²), F (1, 45) = 2.97, *ns*. Vertical bars denote .95 confidence intervals.

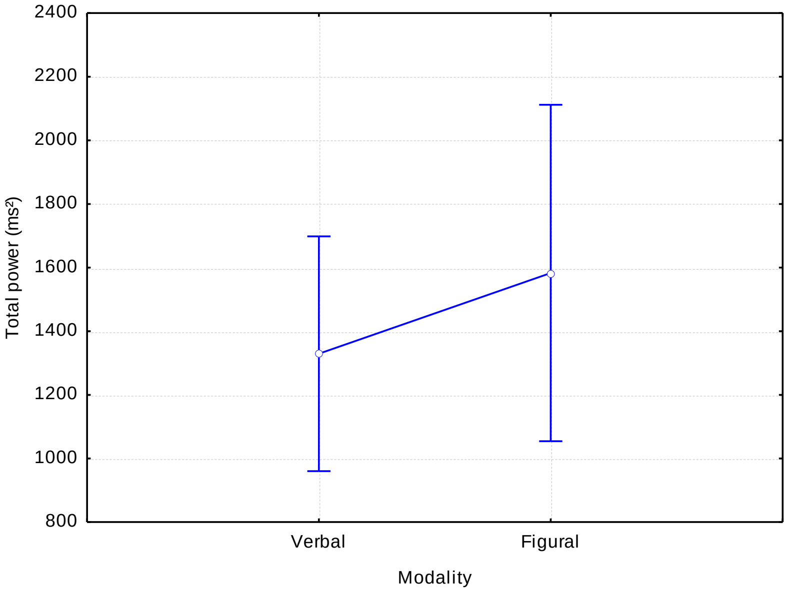

Figure 44. Main effect of modality for total power (ms²), F (1, 45) = 1.91, *ns*. Vertical bars denote .95 confidence intervals.

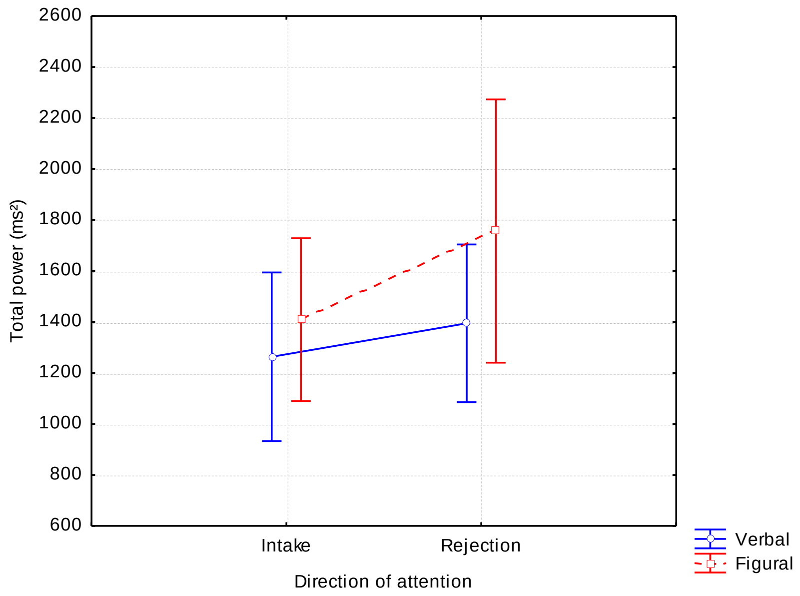

Figure 45. Interaction effect between direction of attention x modality for total power (ms²), *F* (1, 45) = .60, *ns*. Vertical bars .95 confidence intervals.

- HF

Table 17 illustrates the results of the two-way ANOVA for HF power with the repeated factors direction of attention and modality.

Table 17. Results of 2-way ANOVA for HF (ms²) with repeated factors: direction of attention (intake, rejection) and modality (verbal, figural).

Effect	df Effect	MS Effect	df Error	MS Error	F	Sig.	Part. η²
direction of attention	1	296676.38	45	92608.95	3.20	.080	.066
modality	1	91635.21	45	103155.72	.89	.351	.019
direction of attention * modality	1	31090.80	45	99847.44	.31	.580	.007

Note. df = degrees of freedom, MS = Mean Square.

There was no significant main effect of direction of attention, *F* (1, 45) = 3.20, *ns*, as well as no significant main effect of modality, *F* (1, 45) = .89, *ns*. Furthermore, a significant interaction effect between direction of attention and modality could not be detected, *F* (1, 45) = .31, *ns*.

These results indicate that HF power did not differ significantly between the environmental intake and the environmental rejection condition.

See Figure 46, Figure 47, and Figure 48 for graphs of the main effects of direction of attention and modality and the interaction effect between direction of attention and modality for HF power.

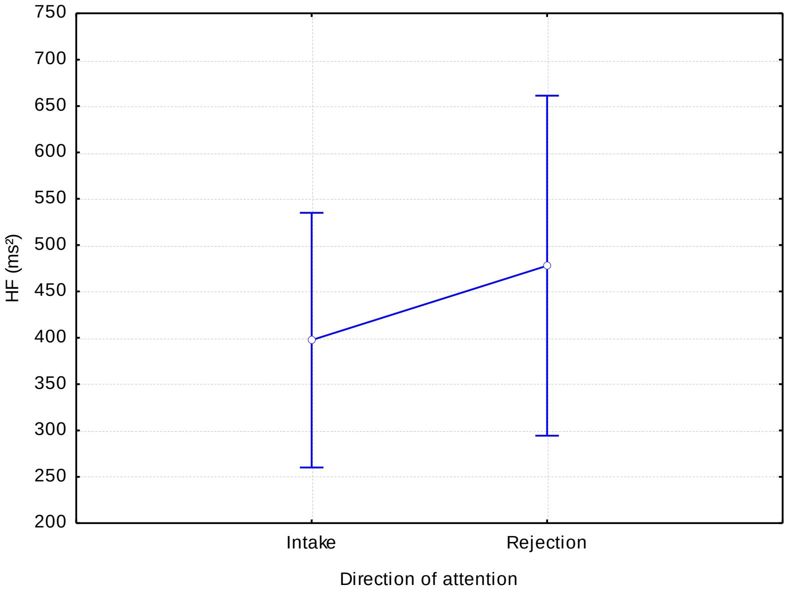

Figure 46. Main effect of direction of attention for HF (ms²), *F* (1, 45) = 3.20, *ns*. Vertical bars denote .95 confidence intervals.

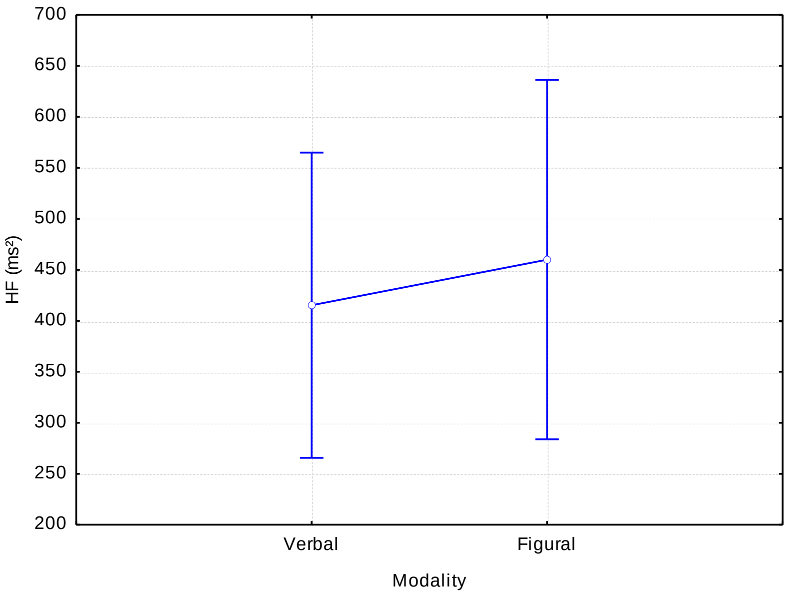

Figure 47. Main effect of modality for HF (ms²), *F* (1, 45) = .89, *ns*. Vertical bars denote .95 confidence intervals.

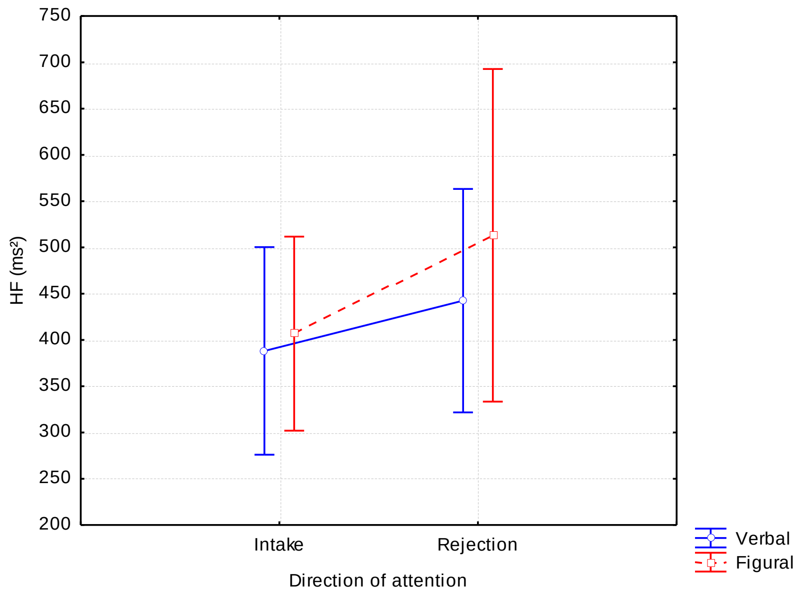

Figure 48. Interaction effect between direction of attention and modality for HF (ms²), F (1, 45) = .31, *ns*. Vertical bars denote .95 confidence intervals.

3.3 Examination of task execution

The examination of task execution was analyzed descriptively.

3.3.1 Verbal intake

Participants had to listen to a text about a fictitious state in Africa and try to memorize as many facts as possible. Afterwards, participants had to answer questions on the presented text. Out of 14 possible correct answers participants answered a mean of 7.28 ± 2 questions correctly (see Table 18).

3.3.2 Figural intake

Participants were presented with 10 photos and instructed to try to memorize as many photos as possible. Subsequently, they were presented with 20 photos and had to indicate if they had seen this photo in the presentation. Participants correctly identified a mean of 15 ± 3 photos (see Table 18).

3.3.3 Verbal rejection

Participants had to create as many words as possible beginning with a given syllable and try to memorize these words. Participants listed a mean of 9 ± 3 words (see Table 18).

3.3.4 Figural rejection

Participants were presented with four incomplete figures and were instructed to complete those figures in their heads and memorize them. Subsequently, they had to complete the figures according to their creations on paper. Participants completed a mean of 3.80 ± .40 figures (see Table 18).

Table 18. Descriptive analysis of the examination of task execution.

Task	Mean	SD	Min.	Max.
Verbal intake (number of correctly answered questions)	7.28	2.01	2.00	10.00
Figural intake (number of correctly identified photos)	15.09	3.13	8.00	19.00
Verbal rejection (number of created words)	8.91	3.39	4.00	14.00
Figural rejection (number of completed figures)	3.80	.40	3.00	4.00

Note. SD = Standard Deviation.

4 Discussion

This study was aimed at investigating effects of the direction of attention (attention directed towards the environment vs. internally directed attention) on DC potentials, heart rate, and parameters of heart rate variability. Two intake and two rejection tasks, with a figural and a verbal component, were created.

4.1 DC potentials and direction of attention

DC potential shifts were analyzed over the course of the attention tasks at frontal, central, and parietal midline locations. It was hypothesized that tasks requiring rejection of the environment and therefore internally directed attention are associated with more positive DC potential changes compared to tasks requiring intake of the environment and thus externally directed attention. Moreover, the effects of the direction of attention were examined in verbal and figural tasks, in order to take account for modality effects on the direction of attention.

In line with the findings of Trimmel and Poelzl (2006), who reported a positive DC potential shift for the rejection of background noise, DC potential shifts significantly increased in positivity over the course of the attention tasks in the environmental rejection condition, whereas a negative DC potential shift over the course of the attention tasks could be demonstrated for the environmental intake condition. These effects were independent of location. Furthermore, it could be determined that the direction of attention is not subject to modality effects.

As positive DC potential shifts are a sign of reduced excitability and therefore reflect cortical inhibition (Rowland, 1974; Marczynski & Karmos; 1978, Rösler et al., 1997), one can thus conclude that internally directed attention is accompanied by cortical inhibition. This finding is in line with Cooper et al. (2003), who investigated the relationship between alpha and direction of attention and reported increased alpha amplitudes during internally directed attention. They concluded that this reflects active inhibition necessary for internally driven mental operations. In environmental rejection tasks one has to actively suppress external information, in order to be able to focus on the cognitive manipulation involved with the task itself. It is therefore possible that the cortical inhibition facilitates the suppression of external information and the focusation of one's attention on internal cognitive operations.

On the contrary, negative DC potential shifts are a sign of higher excitability and therefore reflect cortical activation (Bauer & Nirnberger, 1981; Fuster, 1973; Fuster & Alexander, 1971; Rösler, et al., 1997; Stamm & Rosen, 1972). It can therefore be concluded that the environmental intake condition is accompanied by cortical activation. There is evidence (Trimmel et al., 1996; Pleydell-Pearce, 1994; Haider, Groll-Knapp, & Trimmel, 1990) that negative DC potential shifts are associated with environmental-related attention and performance. This can be seen in line with the finding that tasks requiring one's attention directed towards the environment are associated with negative DC potential shifts.

One can therefore conclude that the distinctive pattern in DC potential shifts produced by tasks requiring rejection of the environment compared to the pattern produced by tasks requiring the intake of the environment may give insight into cortical activation in response to variations in the direction of attention. Direct current brain potential shifts are therefore able to reflect attentional processes in terms of the direction of attention, independent of the location and of the type of modality.

Further research could, for example, be directed towards matching intake and rejection tasks in task difficulty in order to account for possible effects of task difficulty.

4.2 Heart rate and direction of attention

Baseline heart rate was compared to heart rate during intake and rejection tasks. It was hypothesized that acceptance of the environment (intake tasks) is associated with heart rate deceleration compared to baseline heart rate and that rejection of the environment (rejection tasks) produces heart rate acceleration compared to baseline heart rate.

Contrary to these hypotheses no significant effects were found, neither between heart rate during the baseline and the intake tasks, nor between heart rate during the baseline and the rejection tasks. These results do not coincide with the findings of Lacey (1959), Lacey et al. (1963), Obrist (1963), and Lacey & Lacey (1974).

In the present study mean heart rate was evaluated for a 1-minute time interval, whereas Lacey et al. (1963) and Obrist (1963) used two-minute intervals for their attention tasks. It is therefore possible that a slightly different result could have been obtained if heart rate had been averaged over a two-minute interval for the attention tasks. Moreover, heart rate for the baseline condition was averaged over a five-minute interval and was obtained with subjects first filling in the noise questionnaire and after completion interacting with the investigators. It is possible that this distorted the measurement of baseline heart rate.

Moreover, Lacey et al. (1963) used an entirely different method for baseline measurement, as they used the 12 fastest cardiac cycles in the one minute preceding the alerting announcement of the upcoming stimulus condition.

Furthermore, the first 60 seconds of the attention tasks were analyzed and therefore an orienting response possibly distorted the measurements.

4.3 Heart rate variability and direction of attention

Several parameters of heart rate variability were compared between the intake and the rejection condition.

It was hypothesized that HRV, as measured by SDNN, has higher values in the environmental rejection condition than in the environmental intake condition. However, no significant effect was found in the present study. Further analysis revealed no significant effects for RMSSD and pNN50 as well.

Moreover, it was hypothesized that the LF power of HRV is higher in the environmental rejection condition than in the environmental intake condition. Contrary to this hypothesis, LF power did not differ significantly between the environmental intake and the environmental rejection condition. Further analysis revealed no significant effects for total power and HF as well.

The hypotheses for the time domain parameter SDNN and the frequency domain parameter LF were based on a single study conducted by Middleton et al. (1999). In view of this fact it is not as surprising that the present study would come to different conclusions.

Furthermore, Middleton et al. do not give a detailed account of the time intervals used for the attention tasks in their study. They only listed a time frame of six minutes for the RVIP task (an intake task). It can thus be assumed that the time intervals used by Middleton et al. exceeded the time intervals used in the present study. One can therefore speculate that using a one-minute interval for the attention tasks for calculating the spectrum of the HRV signal in the present study contributes to the fact that no significant effects are found. Therefore, further research using longer time intervals is advisable.

Moreover, as mentioned above, the first 60 seconds of the attention tasks were analyzed and an orienting response possibly distorted the measurements for parameters of heart rate variability as well. Further research, excluding the first 20 seconds of the attention tasks in order to exclude a possible confounding effect of the orienting response, is advised.

4.4 Conclusion

Even though the intake-rejection paradigm had been studied extensively over the past two decades in regard to EEG activity in the alpha, beta, and delta frequency bands (see i.e. Cooper et al, 2006; Cooper et al., 2003; Harmony et al. 1996; Ray & Cole, 1985 etc.), the present study is the first study to investigate the effects of tasks requiring intake or rejection of the environment on DC potential shifts. Whereas the environmental rejection condition is accompanied by positive DC potential changes over the course of the attention tasks, the environmental intake condition is accompanied by negative DC potential changes over the course of the attention tasks.

No significant effects are demonstrated comparing average heart rate during baseline with average heart rate during both attentional conditions respectively. Furthermore, no significant effects of the direction of attention could be shown for parameters of heart rate variability.

ABSTRACT

Brain DC potentials are discussed as an indication of cortical activity and are related to the investigated cognitive processes. Moreover, activity in the cardiovascular system has been associated with the understanding of attentional processes. In this study the effect of the direction of attention (environmental intake vs. environmental rejection) on DC potential shifts, heart rate, and parameters of heart rate variability was examined. Brain DC potentials were recorded at Fz, Cz, and Pz midline locations. 46 subjects with a mean age of 24 ± 4 years were subjected to two intake and two rejection tasks. The environmental rejection condition was associated with positive DC potential changes over the course of the attention tasks, whereas the environmental intake condition was associated with negative DC potential changes. These effects were location independent and independent of modality. However, no significant differences could be found between average heart rate and baseline heart rate in both attention conditions. Furthermore, no significant effects were demonstrated for measures of HRV in regards to the intake and rejection condition.

ZUSAMMENFASSUNG

DC-Potentiale werden als ein Indikator für kortikale Aktivität diskutiert und stehen in engem Zusammenhang mit den untersuchten kognitiven Prozessen. Darüberhinaus wurde kardiovaskuläre Aktivität mit Aufmerksamkeitsprozessen in Zusammenhang gebracht. In dieser Studie wurde der Effekt der Richtung der Aufmerksamkeit (external gerichtete Aufmerksamkeit vs. internal gerichtete Aufmerksamkeit) auf DC-Potentialveränderungen, Herzrate und Parameter der Herzratenvariabilität untersucht. DC-Potentiale wurden von Fz, Cz und Pz abgeleitet. 46 Versuchspersonen mit einem mittleren Alter von 24 ± 4 Jahren mussten jeweils zwei Aufmerksamkeitsaufgaben aus dem Bereich der internalen Aufmerksamkeit und zwei aus dem Bereich der externalen Aufmerksamkeit absolvieren. Die internale Aufmerksamkeitsbedingung ging mit positiven DC-Potentialveränderungen einher, während die externale Aufmerksamkeitsbedingung mit negativen DC-Potentenialveränderungen einherging. Dieser Effekt war unabhängig von Elektrodenposition und Modalität. Keine signifikanten Effekte konnten für die Herzrate und Parameter der Herzratenvariabilität festgestellt werden.

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APPENDIX A: STUDY MATERIALS

1 Verbal Intake

1.1 Answer sheet

See Figure A 1 for the answer sheet used in the verbal intake condition "Listening task". The answer sheet was the same for both parallel versions.

Zuhöraufgabe

Versuchen Sie die folgenden Fragen zum eben gehörten Text zu beantworten.

Name des Staates: ________________________

Prozentanteil der Schwarzen an der Gesamtbevölkerung: ______%

Der beschriebene Staat hat _____________ Einwohner.

Name der Partei, die als Sieger aus den ersten freien Wahlen hervorging:
____

Das Land war damals eine ____________________ Kolonie.

Die bedeutendsten landwirtschaftlichen Produkte sind:

___________________ ___________________

___________________ ___________________

___________________ ___________________

Wie viel Prozent der Bevölkerung arbeiten jetzt noch in der Landwirtschaft? ______%

Der Anteil der Weißen in der Hauptstadt beträgt: ______%

Als wievielter Staat wurde das beschriebene Land in die UNO aufgenommen? Als _______ Staat.

Figure A 1. Answer sheet used in the verbal intake condition "Listening task".

2 Figural Intake

2.1 Photographs of trees

2.1.1 Parallel version A

See Figure A 2 for the photographs used for figural intake "Recognizing photographs of trees", parallel version A.

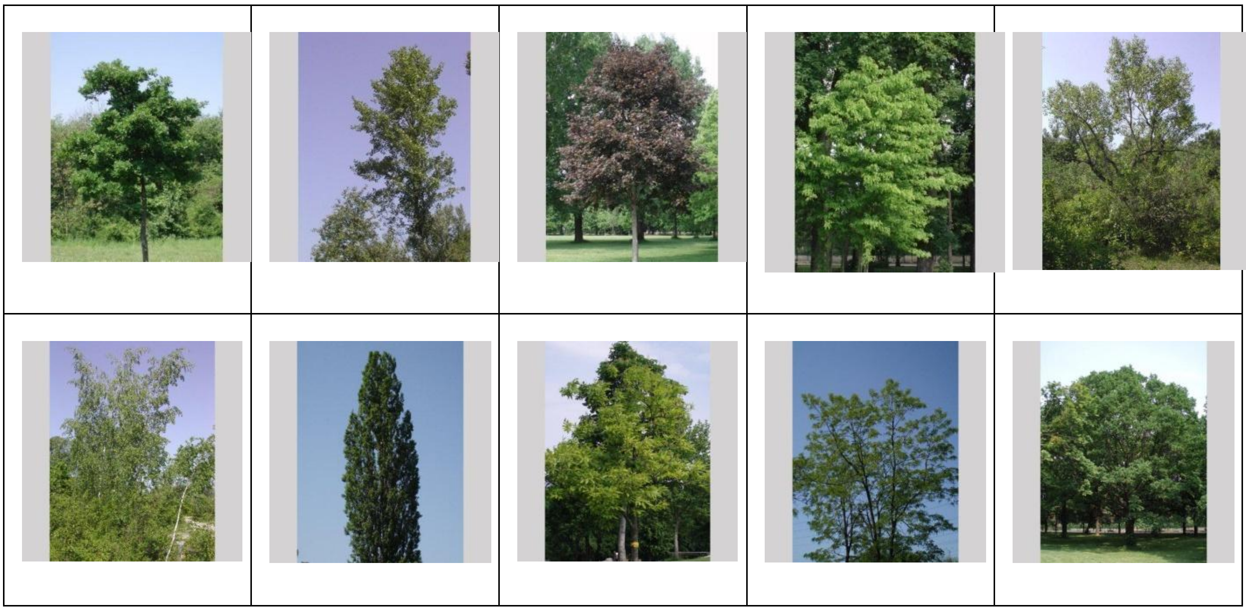

Figure A 2. Photographs presented during figural intake - parallel version A.

2.1.2 Parallel version B

See Figure A 3 for the photographs used for figural intake “Recognizing photographs of trees”, parallel version B.

Figure A 3. Photographs presented during figural intake - parallel version B.

2.2 Answer sheet

See Figure A 4 for the answer sheet used in the figural intake condition “Recognizing photographs of trees”. The answer sheet was the same for both parallel versions.

Baumfotos erkennen

Bitte sehen Sie sich die Fotos auf der Vorlage an und kreuzen Sie für jedes Foto an, ob es in der eben gezeigten Präsentation vorgekommen ist oder nicht.

JA – Foto ist vorgekommen
Nein – Foto ist nicht vorgekommen

	JA	NEIN
1		
2		
3		
4		
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20		

Figure A 4. Answer sheet used in the figural intake condition “Recognizing photographs of trees”.

2.3 Template

2.3.1 Parallel Version A

See Figure A 5 for template used in the figural intake condition “Recognizing photographs of trees”, parallel version A.

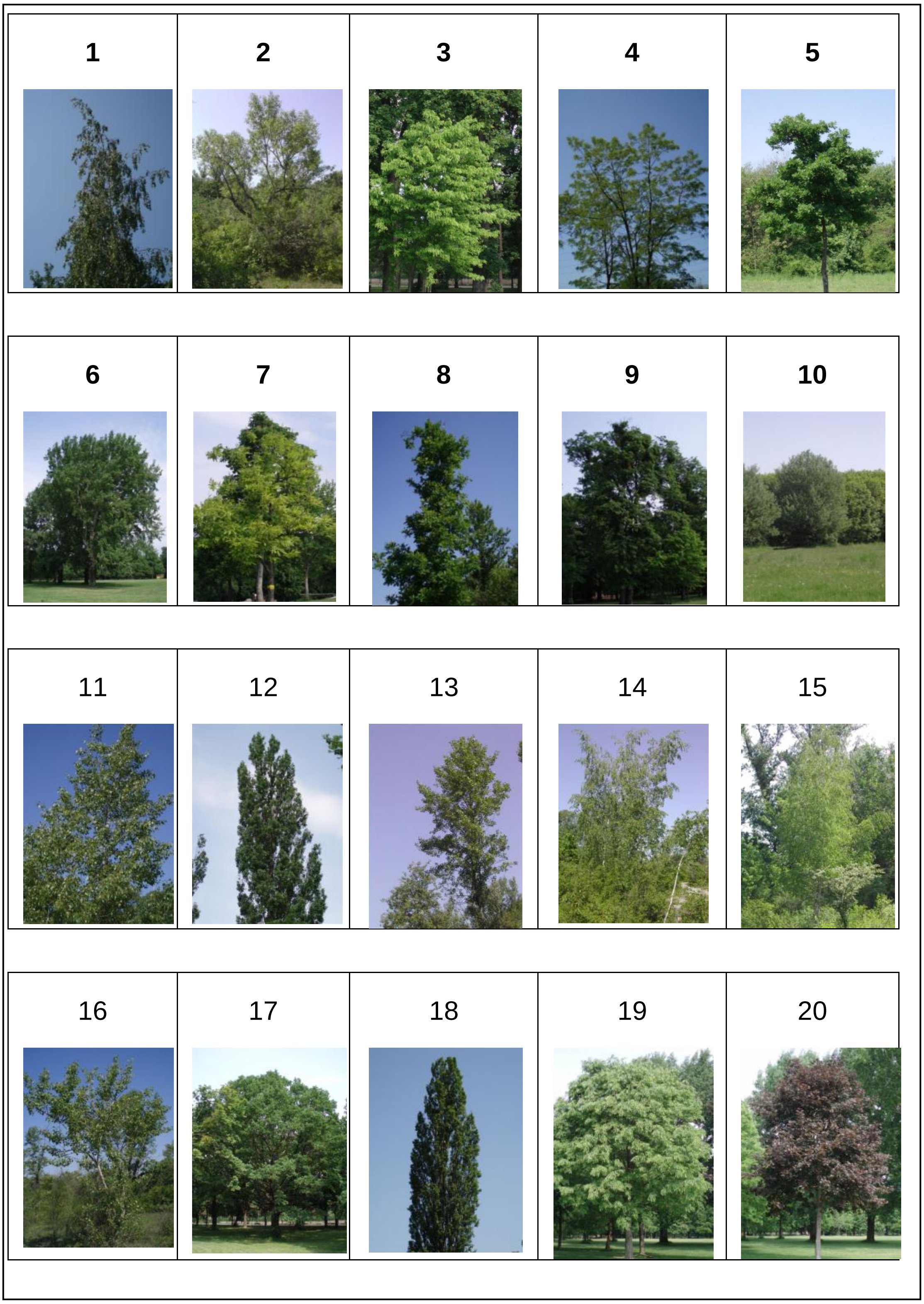

Figure A 5. Laminated template used in the figural intake condition “Recognizing photographs of trees”, parallel version A.

2.3.2 Parallel version B

See Figure A 6 for the template used in the figural intake condition “Recognizing photographs of trees”, parallel version B.

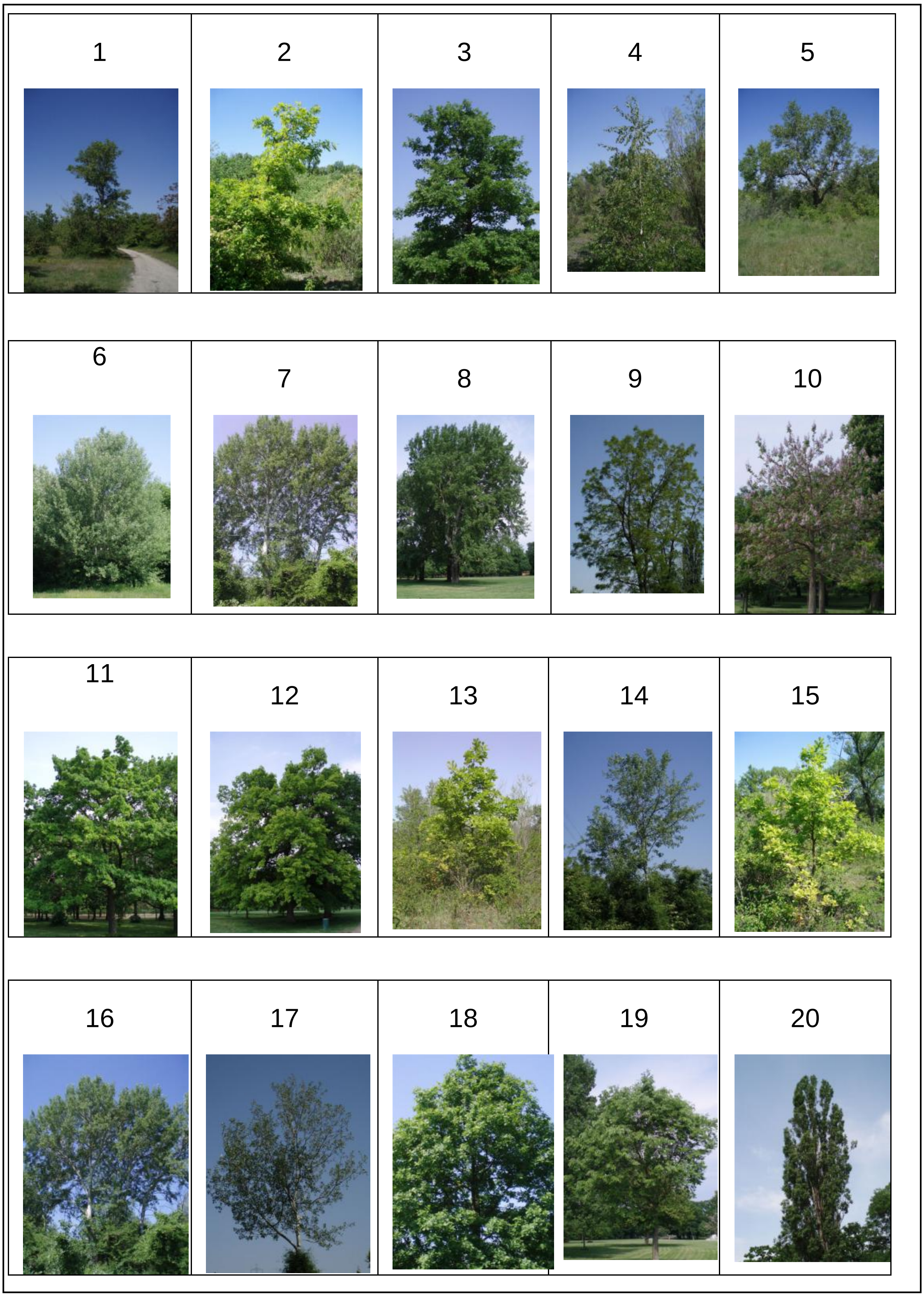

Figure A 6. Laminated template used in the figural intake condition “Recognizing photographs of trees”, parallel version B.

3 Verbal Rejection

3.1 Answer sheet

See Figure A 7 for the answer sheet used in the verbal rejection condition “Creating words”. The answer sheet was the same for both parallel versions.

Wörter bilden

Bitte schreiben Sie hier jene Wörter auf, die Sie sich während der Übung gemerkt haben.

Figure A 7. Answer sheet used in the verbal rejection condition “Creating words”.

APPENDIX B: STATISTICAL ANALYSIS

1 Descriptive statistics

1.1 DC potentials

1.1.1. Verbal intake

See Table B 1 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal intake condition at the recording location Fz.

Table B 1. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Fz for the verbal intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-145.03	185.24	14.31	74.34
Attention task	50-79s	-240.13	317.68	22.31	110.37
	80-109s	-208.83	380.36	47.38	128.08
	110-139s	-296.69	385.19	46.69	128.91
Examination of task execution	140-169s	-313.03	254.60	-37.52	135.12
	170-199s	-248.93	263.00	-30.81	110.89
	200-229s	-206.44	272.55	-17.57	82.97

Note. M = Mean, SD = Standard Deviation.

See Table B 2 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal intake condition at the recording location Cz.

Table B 2. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Cz for the verbal intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-171.73	128.62	-9.42	61.21
Attention task	50-79s	-181.15	233.41	-19.57	93.79

Task Segment	Time interval	Min.	Max.	M	SD
Attention task	80-109s	-229.42	277.71	-8.55	118.86
	110-139s	-241.40	334.24	.98	119.09
Examination of task execution	140-169s	-361.88	232.40	-50.33	119.59
	170-199s	-231.19	187.27	-36.91	92.36
Task Segment	Time interval	Min.	Max.	M	SD
Examination of task execution	200-229s	-219.87	220.65	-28.44	80.47

Note. M = Mean, SD = Standard Deviation.

See Table B 3 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal intake condition at the recording location Pz.

Table B 3. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Pz for the verbal intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-146.98	111.18	-14.01	53.32
Attention task	50-79s	-267.62	165.47	-26.74	81.08
	80-109s	-306.65	166.54	-45.03	106.39
	110-139s	-378.70	147.88	-50.03	111.87
Examination of task execution	140-169s	-345.69	191.14	-59.79	122.50
	170-199s	-230.63	187.94	-24.94	96.56
	200-229s	-265.02	187.73	-29.89	83.30

Note. M = Mean, SD = Standard Deviation.

1.1.2. Figural intake

See Table B 4 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural intake condition at the recording location Fz.

Table B 4. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Fz for the figural intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-258.87	159.63	10.88	85.98
Attention task	50-79s	-508.96	235.13	19.49	125.90
	80-109s	-1011.22	277.48	18.24	198.43
	110-139s	-1143.40	264.66	7.66	217.48
Examination of task execution	140-169s	-910.27	270.46	-54.57	199.15
	170-199s	-926.08	265.95	-56.32	179.11
	200-229s	-838.82	112.24	-57.88	141.93

Note. M = Mean, SD = Standard Deviation.

See Table B 5 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural intake condition at the recording location Cz.

Table B 5. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Cz for the condition “intake figural”.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-308.32	151.04	-6.08	80.56
Attention task	50-79s	-514.90	301.27	-3.12	118.11
	80-109s	-952.40	258.36	-7.52	177.48
	110-139s	-1063.12	294.29	-2.24	203.52
Examination of task execution	140-169s	-832.20	213.00	-39.40	164.07
	170-199s	-782.75	145.57	-29.81	136.44
	200-229s	-751.19	136.68	-40.07	122.39

Note. M = Mean, SD = Standard Deviation.

See Table B 6 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution

(140-169s, 170-199s, 200-229s) for the figural intake condition at the recording location Pz.

Table B 6. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Pz for the figural intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-214.19	63.66	-19.73	61.22
Attention task	50-79s	-349.96	121.91	-31.08	86.51
	80-109s	-788.17	191.08	-53.93	146.69
	110-139s	-975.97	272.00	-74.71	171.90
Examination of task execution	140-169s	-783.32	207.48	-71.36	161.93
	170-199s	-811.13	153.43	-29.85	148.62
	200-229s	-687.73	202.65	-26.68	133.30

Note. M = Mean, SD = Standard Deviation.

1.1.3. Verbal rejection

See Table B 7 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal rejection condition at the recording location Fz.

Table B 7. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Fz for the verbal rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-253.96	214.65	36.11	93.43
Attention task	50-79s	-445.71	406.29	77.90	152.80
	80-109s	-410.12	725.76	114.85	196.07
	110-139s	-389.74	687.29	123.13	192.08
Examination of task execution	140-169s	-265.22	470.71	25.97	153.77
	170-199s	-213.07	319.27	12.24	109.51
	200-229s	-258.69	269.18	-4.51	90.65

Note. M = Mean, SD = Standard Deviation.

See Table B 8 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal rejection condition at the recording location Cz.

Table B 8. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Cz for the verbal rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-137.97	138.47	19.71	78.06
Attention task	50-79s	-260.45	371.36	44.02	125.96
	80-109s	-222.02	686.26	70.15	169.34
	110-139s	-242.17	654.03	79.67	169.83
Examination of task execution	140-169s	-261.18	380.49	4.55	130.00
	170-199s	-195.15	214.43	8.20	105.02
	200-229s	-254.34	190.73	-3.59	96.77

Note. M = Mean, SD = Standard Deviation.

See Table B 9 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal rejection condition at the recording location Pz.

Table B 9. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Pz for the verbal rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-119.84	145.08	.56	57.97
Attention task	50-79s	-260.45	187.96	3.88	94.17
	80-109s	-275.54	479.10	5.39	135.67
	110-139s	-271.73	498.69	-1.01	138.51
Examination of task execution	140-169s	-296.78	283.74	-23.55	118.98
	170-199s	-171.07	276.34	10.35	97.43
	200-229s	-164.71	164.52	-17.60	77.96

Note. M = Mean, SD = Standard Deviation.

1.1.4. Figural rejection

See Table B 10 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural rejection condition at the recording location Fz.

Table B 10. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Fz for the figural rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-259.81	290.05	22.04	90.26
Attention task	50-79s	-379.38	392.70	56.77	145.96
	80-109s	-409.32	507.00	75.87	174.78
	110-139s	-445.81	471.35	84.27	180.50
Examination of task execution	140-169s	-410.72	398.37	9.43	148.24
	170-199s	-243.60	251.78	-12.24	119.80
	200-229s	-245.07	229.91	-15.79	98.11

Note. M = Mean, SD = Standard Deviation.

See Table B 11 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural rejection condition at the recording location Cz.

Table B 11. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Cz for the figural rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-328.82	380.23	29.98	112.09
Attention task	50-79s	-392.05	682.29	56.58	165.68
	80-109s	-309.24	608.97	85.17	177.97
	110-139s	-303.13	510.23	91.70	181.75
Examination of task execution	140-169s	-354.46	377.99	25.22	161.91
	170-199s	-319.41	218.06	-10.41	114.49

Task Segment	Time interval	Min.	Max.	M	SD
Examination of task execution	200-229s	-278.41	143.11	-29.92	90.09

Note. M = Mean, SD = Standard Deviation.

See Table B 12 for descriptive statistics of the minimum, maximum, and mean DC potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural rejection condition at the recording location Pz.

Table B 12. Minimum, maximum, mean, and standard deviations for DC potential amplitudes (µV) at Pz for the figural rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-328.82	320.37	-7.45	103.18
Attention task	50-79s	-392.05	361.23	-1.56	120.51
	80-109s	-370.26	420.53	11.08	132.32
	110-139s	-448.77	403.24	.55	144.34
Examination of task execution	140-169s	-355.62	207.88	-22.42	128.44
	170-199s	-354.54	180.07	-17.15	113.68
	200-229s	-278.41	206.94	-27.90	90.10

Note. M = Mean, SD = Standard Deviation.

1.2 Vertical EOG

1.2.1. Verbal intake

See Table B 13 for descriptive statistics of the minimum, maximum, and mean vertical EOG amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal intake condition.

Table B 13. Minimum, maximum, mean, and standard deviations for EOG amplitudes (µV) for the verbal intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-125.16	420.41	29.71	95.86
Attention task	50-79s	-145.95	580.11	59.16	147.02

Task Segment	Time interval	Min.	Max.	M	SD
Attention task	80-109s	-194.19	674.57	96.39	188.34
	110-139s	-240.52	568.87	78.88	186.68
Examination of task execution	140-169s	-344.67	360.11	-69.00	154.32
	170-199s	-370.89	259.25	-47.06	145.22
	200-229s	-289.79	256.38	-22.88	109.85

Note. M = Mean, SD = Standard Deviation.

1.2.2. Figural intake

See Table B 14 for descriptive statistics of the minimum, maximum, and mean vertical EOG amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural intake condition.

Table B 14. Minimum, maximum, mean, and standard deviations for EOG amplitudes (µV) for the figural intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-257.17	213.43	57.14	93.96
Attention task	50-79s	-219.45	406.01	68.55	130.93
	80-109s	-238.34	494.52	94.38	132.66
	110-139s	-266.30	472.62	87.68	131.54
Examination of task execution	140-169s	-256.17	548.60	-34.89	167.69
	170-199s	-305.54	328.10	-32.12	130.83
	200-229s	-222.19	415.01	-4.60	111.85

Note. M = Mean, SD = Standard Deviation.

1.2.3. Verbal rejection

See Table B 15 for descriptive statistics of the minimum, maximum, and mean vertical EOG amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal rejection condition.

Table B 15. Minimum, maximum, mean, and standard deviations for EOG amplitudes (µV) for the verbal rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-401.38	413.70	43.07	138.04
Attention task	50-79s	-322.52	434.19	75.58	156.97
	80-109s	-412.25	408.24	50.93	168.37
	110-139s	-503.59	434.72	43.81	175.74
Examination of task execution	140-169s	-392.79	336.20	-60.08	155.48
	170-199s	-317.20	250.56	-27.65	129.42
	200-229s	-291.78	205.15	-20.20	109.23

Note. M = Mean, SD = Standard Deviation.

1.2.4. Figural rejection

See Table B 16 for descriptive statistics of the minimum, maximum, and mean vertical EOG amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for figural rejection condition.

Table B 16. Minimum, maximum, mean, and standard deviations for EOG amplitudes (µV) for the figural rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-429.40	276.79	46.77	141.44
Attention task	50-79s	-344.50	407.92	81.62	154.03
	80-109s	-357.91	436.88	85.19	175.65
	110-139s	-411.58	523.49	70.34	188.91
Examination of task execution	140-169s	-515.35	304.31	-69.14	162.38
	170-199s	-428.19	431.47	-51.78	142.52
	200-229s	-399.89	245.44	-35.30	113.92

Note. M = Mean, SD = Standard Deviation.

1.3 Skin potential

1.3.1. Verbal intake

See Table B 17 for descriptive statistics of the minimum, maximum, and mean skin potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal intake condition.

Table B 17. Minimum, maximum, mean, and standard deviations for skin potential amplitudes (µV) for the verbal intake condition

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-1704.65	1900.23	143.62	745.34
Attention task	50-79s	-1405.44	2489.32	359.74	902.76
	80-109s	-2624.96	3065.96	29.42	1272.31
	110-139s	-3262.61	3063.68	-7.32	1550.17
Examination of task execution	140-169s	-2047.19	2516.72	213.72	1235.76
	170-199s	-2474.13	2166.47	176.64	949.29
	200-229s	-1549.11	2291.94	107.11	666.77

Note. M = Mean, SD = Standard Deviation.

1.3.2. Figural intake

See Table B 18 for descriptive statistics of the minimum, maximum, and mean skin potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural intake condition.

Table B 18. Minimum, maximum, mean, and standard deviations for skin potential amplitudes (µV) for the figural intake condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-1518.21	1570.98	19.73	706.73
Attention task	50-79s	-2564.64	2882.97	3.02	1186.73
	80-109s	-3645.68	5258.90	159.52	1815.16
	110-139s	-4444.35	7889.24	344.95	2321.84
Examination of task execution	140-169s	-3036.16	4005.72	112.00	1520.19

Task Segment	Time interval	Min.	Max.	M	SD
Examination of task execution	170-199s	-2534.12	2017.03	-311.28	1178.02
	200-229s	-2088.31	1424.01	-134.99	731.08

Note. M = Mean, SD = Standard Deviation.

1.3.3. Verbal rejection

See Table B 19 for descriptive statistics of the minimum, maximum, and mean skin potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the verbal rejection condition.

Table B 19. Minimum, maximum, mean, and standard deviations for skin potential amplitudes (µV) for the verbal rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-1500.63	1383.34	9.24	646.93
Attention task	50-79s	-2747.55	2612.08	-195.89	1182.21
	80-109s	-4012.66	4869.37	-93.09	1627.41
	110-139s	-4048.60	7000.25	82.72	1977.57
Examination of task execution	140-169s	-2161.06	2980.74	94.45	1245.52
	170-199s	-1743.88	1863.72	-157.00	897.36
	200-229s	-3097.01	2199.01	-97.00	820.15

Note. M = Mean, SD = Standard Deviation.

1.3.4. Figural rejection

See Table B 20 for descriptive statistics of the minimum, maximum, and mean skin potential amplitudes and their standard deviations for the instructions (30-49s), attention tasks (50-79s, 80-109s, 110-139s), and their respective examination of task execution (140-169s, 170-199s, 200-229s) for the figural rejection condition.

Table B 20. Minimum, maximum, mean, and standard deviations for skin potential amplitudes (µV) for the figural rejection condition.

Task Segment	Time interval	Min.	Max.	M	SD
Instruction	30-49s	-1775.03	1862.34	130.46	867.05
Attention task	50-79s	-3301.60	2668.97	159.38	1328.19

Task Segment	Time interval	Min.	Max.	M	SD
Attention task	80-109s	-3486.96	4452.51	161.15	1661.21
	110-139s	-3557.73	5825.46	179.15	1926.72
Examination of task execution	140-169s	-2392.63	2204.10	178.04	1272.81
	170-199s	-3646.44	3315.97	21.42	1227.98
	200-229s	-1759.90	1103.68	44.03	640.00

Note. M = Mean, SD = Standard Seviation.

1.4 Comparison of DC potentials, vertical EOG, and skin potential

Table B 21 shows the mean values and standard deviation for DC potential shifts (µV), vertical EOG (µV), and skin potential (µV) for the intake and figural attention conditions for epochs of 50-79s, 80-109s, and 110-139s.

Table B 21. Mean values for brain DC potential shifts (µV), vertical EOG (µV), and skin potential (µV) for intake and rejection attention tasks for epochs of 50-79s, 80-109s, and 110-139s.

Epoch (s)	DC potential shifts				VEOG				SP			
	Intake		Figural		Intake		Figural		Intake		Figural	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
50-79	-6.45	10.99	39.60	15.81	63.86	15.48	78.60	16.73	181.38	124.85	-18.26	165.13
80-109	-8.24	15.41	60.42	19.30	95.39	18.57	68.06	18.27	94.47	198.77	34.03	222.71
110-139	-11.94	16.20	63.05	19.55	83.28	19.39	57.07	20.71	168.81	256.64	130.94	269.35

Note. M = Mean, SD = Standard Deviation, VEOG = vertical EOG, and SP = skin potential.

1.5 Heart rate

See Table B 22 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions and for the 5-minute general baseline for heart rate (mean BpM).

Table B 22. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions and for the 5-minute general baseline for heart rate (mean BpM).

Condition	Task segment	Min.	Max.	M	SD
	General Baseline	54.93	90.75	71.92	8.00
Intake verbal	Attention task	54.94	95.21	73.64	10.14

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Examination of task execution	56.38	99.82	76.49	9.23
Intake figural	Attention task	54.71	93.17	72.56	10.12
	Examination of task execution	58.64	99.89	76.99	9.06
Rejection verbal	Attention task	56.19	89.27	72.65	9.50
	Examination of task execution	57.61	99.48	78.34	9.55
Rejection figural	Attention task	56.56	108.16	73.28	10.85
	Examination of task execution	56.33	105.17	78.85	10.19

Note. M = Mean, SD = Standard Deviation.

1.6 Heart rate variability

1.6.1. SDNN

See Table B 23 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions for SDNN (ms).

Table B 23. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions for SDNN (ms).

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Attention task	5.90	86.80	41.85	16.88
	Examination of task execution	9.80	101.10	50.98	17.47
Intake figural	Attention task	11.40	83.20	46.09	16.45
	Examination of task execution	13.30	97.50	53.09	19.09
Rejection verbal	Attention task	9.90	85.30	45.43	16.17
	Examination of task execution	4.80	95.60	54.33	21.08
Rejection figural	Attention task	8.00	102.80	46.29	18.83
	Examination of task execution	10.70	76.30	49.00	15.99

Note. M = Mean, SD = Standard Deviation.

1.6.2. RMSSD

See Table B 24 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions for RMSSD (ms).

Table B 24. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions for RMSSD (ms).

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Attention task	4.40	104.90	37.76	19.92
	Examination of task execution	5.30	84.30	37.11	16.59
Intake figural	Attention task	6.00	106.70	41.72	21.01
	Examination of task execution	4.70	104.40	37.35	18.85
Rejection verbal	Attention task	6.60	109.90	41.47	22.76
	Examination of task execution	5.00	97.70	36.52	17.14
Rejection figural	Attention task	5.80	127.10	42.03	23.09
	Examination of task execution	7.60	89.60	35.73	17.15

Note. M = Mean, SD = Standard Deviation.

1.6.3. pNN50

See Table B 25 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions for pNN50 (%).

Table B 25. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions for pNN50 (%).

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Attention task	.00	75.47	20.37	20.64
	Examination of task execution	.00	62.71	17.57	15.46
Intake figural	Attention task	.00	71.05	22.99	20.10
	Examination of task execution	.00	73.21	18.10	16.80
Rejection verbal	Attention task	.00	70.37	22.06	19.98
	Examination of task execution	.00	65.63	17.12	16.24
Rejection figural	Attention task	.00	85.42	23.63	21.77
	Examination of task execution	.00	57.14	15.92	15.56

Note. M = Mean, SD = Standard Deviation.

1.6.4. LF

See Table B 26 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions for LF (ms^2).

Table B 26. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions for LF (ms^2).

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Attention task	2.70	2542.70	564.11	575.63
	Examination of task execution	2.00	2035.50	416.40	362.91
Intake figural	Attention task	6.80	2580.80	566.52	473.85
	Examination of task execution	8.80	1813.80	576.17	433.30
Rejection verbal	Attention task	2.90	1583.40	544.48	396.48
	Examination of task execution	4.90	1511.10	523.02	357.19
Rejection figural	Attention task	2.50	6028.00	697.92	955.43
	Examination of task execution	3.70	1540.30	498.69	363.68

Note. M = Mean, SD = Standard Deviation.

1.6.5. Total power

See Table B 27 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions for total power (ms^2).

Table B 27. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions for total power (ms^2).

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Attention task	15.80	5821.50	1263.57	1114.11
	Examination of task execution	38.00	6297.50	1036.53	998.18
Intake figural	Attention task	23.30	5754.50	1409.20	1075.45
	Examination of task execution	50.30	3885.60	1299.04	845.58
Rejection verbal	Attention task	11.10	4489.40	1394.81	1041.20
	Examination of task execution	28.60	2942.60	1241.37	750.07
Rejection figural	Attention task	12.70	9534.70	1756.73	1739.07

Condition	Task segment	Min.	Max.	M	SD
Rejection figural	Examination of task execution	26.60	2610.30	1133.24	632.85

Note. M = Mean, SD = Standard Deviation.

1.6.6. HF

See Table B 28 for descriptive statistics of the minimum, maximum, mean, and standard deviation of the 1-minute intervals for the attention tasks and their respective examination of task execution for all conditions for HF (ms^2).

Table B 28. Minimum, maximum, mean, and standard deviation for the attention tasks and their respective examination of task execution for all conditions for HF (ms^2).

Condition	Task segment	Min.	Max.	M	SD
Intake verbal	Attention task	4.40	1978.30	388.14	377.59
	Examination of task execution	4.70	2120.70	323.28	365.29
Intake figural	Attention task	5.00	1901.50	406.78	353.01
	Examination of task execution	4.00	1118.40	331.21	276.49
Rejection verbal	Attention task	3.70	1690.90	442.45	406.54
	Examination of task execution	3.50	1520.70	335.62	289.08
Rejection figural	Attention task	5.00	3395.10	513.08	605.03
	Examination of task execution	8.50	1167.00	305.12	237.60

Note. M = Mean, SD = Standard Deviation.

2 Additional ANOVA results

2.1 DC potentials

2.1.1. Mauchly's Test of Sphericity

See Table B 29 for results of Mauchly's Test of Sphericity for the four-way ANOVA of brain DC potentials with repeated factors direction of attention (intake, rejection), modality (verbal, figural), location (Fz, Cz, Pz) and time (50-79s, 80-109s, 110-139s).

Table B 29. Results of Mauchly's Test of Sphericity of 4-way ANOVA for brain DC potential shifts (µV) with repeated factors.

					Epsilon		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
direction of attention	1.000	.000	0	.	1.000	1.000	1.000
modality	1.000	.000	0	.	1.000	1.000	1.000
location	.990	.423	2	.809	.991	1.000	.500
time	.587	23.417	2	.000***	.708	.724	.500
direction of attention * modality	1.000	.000	0	.	1.000	1.000	1.000
direction of attention * location	.890	5.107	2	.078	.901	.937	.500
modality * location	.994	.250	2	.883	.994	1.000	.500
direction of attention * modality * location	.843	7.490	2	.024*	.865	.896	.500
direction of attention * time	.461	34.078	2	.000***	.650	.661	.500
modality * time	.435	36.581	2	.000***	.639	.650	.500
direction of attention * modality * time	.759	12.106	2	.002**	.806	.832	.500
location * time	.151	82.067	9	.000***	.668	.715	.250
direction of attention * location * time	.324	48.882	9	.000***	.641	.682	.250
modality * location * time	.354	45.114	9	.000***	.704	.756	.250
direction of attention * modality * location * time	.247	60.745	9	.000***	.677	.725	.250

Note. df = degrees of freedom. ***Indicates significant differences $p < .001$, **indicates significant differences $p < .01$, *indicates significant differences $p < .05$.

2.1.2. Bonferroni post hoc test

See Table B 30 for results of Bonferroni post hoc test for the main effect of location for DC potential shifts.

Table B 30. Pairwise comparisons for the main effect of location for DC potential shifts (µV) using Bonferroni adjustment.

					95% Confidence Interval for Difference	
(I) location	(J) location	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
FZ	CZ	25.607	12.951	.162	-6.599	57.812
	PZ	79.814	11.896	.000***	50.232	109.395
CZ	FZ	-25.607	12.951	.162	-57.812	6.599
	PZ	54.207	12.498	.000***	23.128	85.286
PZ	FZ	-79.814	11.896	.000***	-109.395	-50.232
	CZ	-54.207	12.498	.000***	-85.286	-23.128

Note. ***Indicates significant differences *p* < .001.

See Table B 31 for probabilities for Bonferroni post hoc test for the interaction effect between attention and time for DC potential shifts.

Table B 31. Probabilities for post hoc test for the interaction effect between attention x time for DC potential shifts (µV) using the Bonferroni adjustment.

			{1}	{2}	{3}	{4}	{5}	{6}
Cell No.	ATT	TIME	-6.45	-8.24	-11.94	39.6	60.42	63.05
1	Intake	50-79s		1.000	1.000	.000***	.000***	.000***
2	Intake	80-109s	1.000		1.000	.000***	0.000***	.000***
3	Intake	110-139s	1.000	1.000		.000	0.000***	.000***
4	Rejection	50-79s	.000***	.000***	.000***		0.045	.013*
5	Rejection	80-109s	.000***	.000***	.000***	.045*		1.000
6	Rejection	110-139s	.000***	.000***	.000***	.013*	1.000	

Note. Error: Within MSE = 6413.1, df = 90. ***Indicates significant differences *p* < .001, **indicates significant differences *p* < .01, *indicates significant differences *p* < .05.

See Table B 32 for probabilities for Bonferroni post hoc test for the interaction effect between location and time for DC potential shifts.

Table B 32. Probabilities for post hoc test for the interaction effect between location x time for DC potential shifts (μV) using the Bonferroni adjustment.

			{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}
Cell No.	Loc.	Time	44.12	64.08	65.44	19.48	34.81	42.53	-13.88	-20.63	-31.30
1	Fz	50-79s		.001**	.000***	.000***	1.000	1.000	.000***	.000***	.000***
2	Fz	80-109s	.001**		1.000	.000***	.000***	.000***	.000***	.000***	.000***
3	Fz	110-139s	.000***	1.000		.000***	.000***	.000***	.000***	.000***	.000***
4	Cz	50-79s	.000***	.000***	.000***		.029*	.000***	.000***	.000***	.000***
5	Cz	80-109s	1.000	.000***	.000***	.029*		1.000	.000***	.000***	.000***
6	Cz	110-139s	1.000	.000***	.000***	.000***	1.000		.000***	.000***	.000***
7	Pz	50-79s	.000***	.000***	.000***	.000***	.000***	.000***		1.000	.005**
8	Pz	80-109s	.000***	.000***	.000***	.000***	.000***	.000***	1.000		.669
9	Pz	110-139s	.000***	.000***	.000***	.000***	.000***	.000***	.005**	.669	

Note. Error: Within MSE = 1858.6, df = 180. ***Indicates significant differences $p < .001$, **indicates significant differences $p < .01$, *indicates significant differences $p < .05$.

Table B 33 shows the results for Bonferroni post hoc test for the interaction effect between modality and location for DC potential shifts.

Table B 33. Probabilities for post hoc test for the interaction effect between modality x location for DC potential shifts (μV) using the Bonferroni adjustment.

			{1}	{2}	{3}	{4}	{5}	{6}
Cell No.	Modal.	Loc.	72.04	27.78	-18.93	43.72	36.76	-24.94
1	Verbal	Fz		.000***	.000***	.060	.006**	.000
2	Verbal	Cz	.000***		.000***	1.000	1.000	.000
3	Verbal	Pz	.000***	.000***		.000***	.000***	1.000
4	Figural	Fz	.060	1.000	.000***		1.000	.000***
5	Figural	Cz	.006**	1.000	.000***	1.000		.000***
6	Figural	Pz	.000***	.000***	1.000	.000***	.000***	

Note. Error: Within MSE = 12666, df = 90. ***Indicates significant differences $p < .001$, **indicates significant differences $p < .01$.

2.2 Vertical EOG

2.2.1. Mauchly's Test of Sphericity

See Table B 34 for results of Mauchly's Test of Sphericity for the three-way ANOVA of vertical EOG with repeated factors direction of attention (intake, rejection), modality (verbal, figural), location (Fz, Cz, Pz), and time (50-79s, 80-109s, 110-139s).

Table B 34. Results of Mauchly's Test of Sphericity for 3-way ANOVA of vertical EOG (µV) with repeated factors.

					Epsilon		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
direction of attention	1.000	.000	0	.	1.000	1.000	1.000
modality	1.000	.000	0	.	1.000	1.000	1.000
time	.505	30.080	2	.000	.669	.682	.500
direction of attention * modality	1.000	.000	0	.	1.000	1.000	1.000
direction of attention * time	.783	10.772	2	.005	.822	.849	.500
modality * time	.946	2.439	2	.295	.949	.989	.500
direction of attention * modality * time	.657	18.515	2	.000	.744	.764	.500

Note. df = degrees of freedom. *** Indicates statistically significant effects *p* < .001, **indicates statistically significant effects *p* < .01, *indicates statistically significant effects *p* < .05.

2.2.2. Bonferroni post hoc test

Table B 35 shows the results for Bonferroni post hoc test for the interaction effect between direction of attention and time for vertical EOG.

Table B 35. Probabilities for post hoc test for the interaction effect between direction of attention x time for vertical EOG (µV) using the Bonferroni adjustment.

			{1}	{2}	{3}	{4}	{5}	{6}
Cell No.	Att.	Time	63.86	95.39	83.28	78.6	68.06	57.07
1	Intake	50-79s		.030*	.800	1.000	1.000	1.000
2	Intake	80-109s	.030*		1.000	1.000	.110	.000***

			{1}	{2}	{3}	{4}	{5}	{6}
Cell No.	Att.	Time	63.86	95.39	83.28	78.6	68.06	57.07
3	Intake	110-139s	.800	1.000		1.000	1.000	.140
4	Rejection	50-79s	1.000	1.000	1.000		1.000	.490
5	Rejection	80-109s	1.000	.110	1.000	1.000		1.000
6	Rejection	110-139s	1.000	.000***	.140	.490	1.000	

Note. Error: Within MSE = 4515.3, df = 90. ***Indicates significant differences $p < .001$, *indicates significant differences $p < .05$.

2.3 Skin potential

2.3.1. Mauchly's Test of Sphericity

See Table B 36 for results of Mauchly's Test of Sphericity for the three-way ANOVA of skin potential with repeated factors direction of attention (intake, rejection), modality (verbal, figural), location (Fz, Cz, Pz), and time (50-79s, 80-109s, 110-139s).

Table B 36. Results of Mauchly's Test of Sphericity for 3-way ANOVA of skin potential (µV) with repeated factors.

					Epsilon		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
direction of attention	1.000	.000	0	.	1.000	1.000	1.000
modality	1.000	0.000	0	.	1.000	1.000	1.000
time	.153	82.634	2	.000***	.541	.544	.500
direction of attention * modality	1.000	.000	0	.	1.000	1.000	1.000
direction of attention * time	.807	9.428	2	.009**	.838	.867	.500
modality * time	.712	14.927	2	.001**	.777	.799	.500
direction of attention * modality * time	.657	18.511	2	.000***	.744	.764	.500

Note. df = degrees of freedom. ***Indicates statistically significant effects $p < .001$, and **indicates statistically significant effects $p < .01$.

2.3.2. Bonferroni post hoc test

Table B 37 shows the results for Bonferroni post hoc test for the interaction effect between direction of attention and time for skin potential.

Table B 37. Probabilities for post hoc test for the interaction effect between direction of attention x time for skin potential (μV) using the Bonferroni adjustment.

			{1}	{2}	{3}	{4}	{5}	{6}
Cell No.	Att.	Time	181.38	94.47	168.81	-18.26	34.02	130.94
1	Intake	50-79s		1.000	1.000	.001**	.039*	1.000
2	Intake	80-109s	1.000		1.000	.298	1.000	1.000
3	Intake	110-139s	1.000	1.000		.002**	.085	1.000
4	Rejection	50-79s	.001**	.298	.002**		1.000	.034*
5	Rejection	80-109s	.039*	1.000	.085	1.000		.666
6	Rejection	110-139s	1.000	1.000	1.000	.034*	.666	

Note. Error: Within MSE = 103900, df = 90. **Indicates significant differences *p* < .01, *indicates significant differences *p* < .05.

Table B 38 shows the results for Bonferroni post hoc test for the interaction effect between modality and time for skin potential.

Table B 38. Probabilities for post hoc test for the interaction effect between modality x time for skin potential (μV) using the Bonferroni adjustment.

			{1}	{2}	{3}	{4}	{5}	{6}
Cell No.	Modal.	Time	81.925	-31.83	37.700	81.199	160.33	262.05
1	Verbal	50-79s		0.591	1.000	1.000	1.000	0.020**
2	Verbal	80-109s	0.591		1.000	0.610	0.010**	0.000***
3	Verbal	110-139s	1.000	1.000		1.000	0.400	0.001***
4	Figural	50-79s	1.000	0.610	1.000		1.000	0.019**
5	Figural	80-109s	1.000	0.010**	0.400	1.000		0.973
6	Figural	110-139s	0.020**	0.000***	0.001***	0.019**	0.973	

Note. Error: Within MSE = 136300, df = 90. ***Indicates significant differences *p* < .001, **indicates significant differences *p* < .01.

Table B 39 shows the results for Bonferroni post hoc test for the interaction effect between direction of attention and modality and time for skin potential.

Table B 39. Probabilities for post hoc test for the interaction effect between direction of attention x modality x time for skin potential (µV) using the Bonferroni adjustment.

				{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}
Cell no.	Att.	Mod.	Time	359.74	29.425	-7.322	3.0228	159.52	344.95	-195.9	-93.09	82.722	159.38	161.15	179.15
1	I	V	50-79s		0.019**	0.004**	0.006**	1.000	1.000	0.000***	0.000***	0.137	1.000	1.000	1.000
2	I	V	80-109s	0.019**		1.000	1.000	1.000	0.033**	0.762	1.000	1.000	1.000	1.000	1.000
3	I	V	110-139s	0.004**	1.000		1.000	1.000	0.008**	1.000	1.000	1.000	1.000	1.000	1.000
4	I	F	50-79s	0.006**	1.000	1.000		1.000	0.012**	1.000	1.000	1.000	1.000	1.000	1.000
5	I	F	80-109s	1.000	1.000	1.000	1.000		1.000	0.007**	0.318	1.000	1.000	1.000	1.000
6	I	F	110-139s	1.000	0.033**	0.008**	0.012**	1.000		0.000***	0.000***	0.230	1.000	1.000	1.000
7	R	V	50-79s	0.000***	0.762	1.000	1.000	0.007**	0.000***		1.000	0.130	0.007**	0.006**	0.003**
8	R	V	80-109s	0.000***	1.000	1.000	1.000	0.318	0.000***	1.000		1.000	0.319	0.301	0.163
9	R	V	110-139s	0.137	1.000	1.000	1.000	1.000	0.230	0.130	1.000		1.000	1.000	1.000
10	R	F	50-79s	1.000	1.000	1.000	1.000	1.000	1.000	0.007**	0.319	1.000		1.000	1.000
11	R	F	80-109s	1.000	1.000	1.000	1.000	1.000	1.000	0.006**	0.301	1.000	1.000		1.000
12	R	F	110-139s	1.000	1.000	1.000	1.000	1.000	1.000	0.003**	0.163	1.000	1.000	1.000	

Note. Error: Within MSE = 175600, df = 90. ***Indicates significant differences $p < .001$, **indicates significant differences $p < .01$.

2.4 Heart rate

2.4.1. Mauchly's Test of Sphericity

See Table B 40 for results of Mauchly's Test of Sphericity for the one-way ANOVA of heart rate (mean BpM) with repeated factor condition (baseline, intake-verbal, intake-figural).

Table B 40. Results of Mauchly's Test of Sphericity for one-way ANOVA of heart rate (mean BpM) (intake condition) with repeated factors.

					Epsilon		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.726	14.071	2	.001**	.785	.809	.500

Note. df = degrees of freedom. **indicates statistically significant effects $p < .01$.

See Table B 41 for results of Mauchly's Test of Sphericity for the one-way ANOVA of heart rate (mean BpM) with repeated factor condition (baseline, rejection-verbal, rejection-figural).

Table B 41. Results of Mauchly’s Test of Sphericity for one-way ANOVA of heart rate (mean BpM) (rejection condition) with repeated factors.

					Epsilon		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	.812	9.158	2	.010*	.842	.871	.500

Note. df = degrees of freedom. *Indicates statistically significant effects p <.05.

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EDV-Kenntnisse	Microsoft-Office SPSS Statistica Besa 5.2
EEG-Ableitung	BioSemi Hard- und Software