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Self-generated cognitive fluency: Consequences on evaluative judgments

Ulrich von Hecker[1], Paul H. P. Hanel[2], Zixi Jin[1]

and Piotr Winkielman[3, 4]

[1]School of Psychology, Cardiff University, UK

[2]Department of Psychology, University of Essex, UK

[3]University of California, San Diego, USA

[4]SWPS University of Social Sciences and Humanities, Warsaw, Poland

Author Note

Correspondence should be addressed to Ulrich von Hecker, School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff, CF10 3AT, United Kingdom. Electronic mail may be sent to vonheckeru@cardiff.ac.uk.

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Abstract

People can support abstract reasoning by using mental models with spatial simulations. Such models are employed when people represent elements in terms of ordered dimensions (e.g., who is oldest, Tom, Dick, or Harry). We test and find that the process of forming and using such mental models can influence the liking of its elements (e.g., Tom, Dick, or Harry). The presumed internal structure of such models (linear-transitive array of elements), generates variations in processing ease (fluency) when using the model in working memory (see the Symbolic Distance Effect, SDE). Specifically, processing of pairs where elements have larger distances along the order should be easier compared to pairs with smaller distances. Elements from easier pairs should be liked more than elements from difficult pairs (fluency being hedonically positive). Experiment 1 shows that unfamiliar ideographs are liked more when at wider distances and therefore easier to process. Experiment 2 replicates this effect with non-words. Experiment 3 rules out a non-spatial explanation of the effect while Experiments 4 offers a high-powered replication. Experiment 5 shows that the spatial effect spontaneously emerges after learning, even without a task that explicitly focuses on fluency. Experiment 6 employed a shorter array, but yielded no significant results.

225 words

Key Words: symbolic distance effect (SDE), magnitude processing, linear orders, spatial processing, cognitive fluency

Word Count: 8491 (without references)

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1. Introduction

1. 1. Background

Much evidence shows that perceptually or cognitively *fluent* stimuli elicit positive affective responses, as revealed by participants' favourability ratings, or their physiological reactions (Winkielman & Cacioppo, 2001, for a review: Winkielman, Schwarz, Fazendeiro, & Reber, 2003). Things are liked more if easier to perceive and cognize. More generally, participants draw on internal subjective experiences in their judgments of external stimuli (Schwarz & Clore, 1996; Strack, Martin, & Stepper, 1988). Importantly, such experiences may not derive from stimulus features (Anderson, 1981) but reflect the relative effort of stimulus processing, resulting in a cognitive feelings of fluency (Clore, 1992; Jost, Kruglanski, & Nelson, 1998, Schwarz, 1998). Fluency is assumed to be associated with pleasure and positive affective reactions (Winkielman et al., 2003, but see Unkelbach, 2006 for an argument against inherent pleasantness of fluency).

Fluency effects can be elicited by manipulating perceptual effort by variations in repetition, presentation time, or figure-to-ground contrast (e.g., Reber, Winkielman, and Schwarz, 1998, see the mere exposure effect, Zajonc, 1968). For example, in the mere exposure effect, neutral stimuli are liked more after frequent repetition (Bornstein, 1989; Zajonc, 1968), presumably due to greater neural processing efficiency with more repetitions, leading to greater judgments of clarity and distinctness (Desimone, Miller, Chelazzi, & Lueschow, 1995; Witherspoon & Allan, 1985). Fluency can also be manipulated at the conceptual level by placing the stimulus within a predictive or non-predictive semantic context making it easier or harder to derive the stimulus meaning (e.g., Fazendeiro, Winkielman, Luo, & Lorah, 2005; Whittlesea, 1993).

Critically, whether a specific stimulus elicits fluency/disfluency and liking/disliking depends on the exact task performed by the participant, for example, emotionally ambiguous faces being disfluently processed when categorized on emotion, but fluently when categorized on gender which was not ambiguous (see Winkielman, Olszanowski, & Gola (2015). Analog effects showing task dependence of fluency and preferences were observed with brain measures (EEG) of processing difficulty (Kaminska et al., 2020) and have been modelled computationally (Ryali et al, 2020).

1.2. Present Research

Previous studies on fluency have focused on either perceptual factors or on cognitive factors, see above. The present research investigates fluency phenomena during online processing of self-constructed mental models (Greeno, 1989; Hegarty, 2004). We provide evidence for fluency as internally generated, not to be described in terms of external (perceptual), individual stimulus features, or pre-existing semantic contexts. Unlike previous research on conceptual fluency, self-generated fluency does not rely on information or schemata in long-term memory. Rather, this fluency derives from the nature of the self-constructed relations *between* newly learned, individual stimuli. The degree of fluency associated with a stimulus, as we argue, derives from reasoning about the stimulus as it relates to other stimuli when constructing an overall mental representation of all stimuli simultaneously. Differences in fluency are to be expected just because the experimental task taps precisely into the characteristics of this overall representation.

1.3. The Paradigm

The present research involves learning elements on a continuum. For example, after learning a linear rank order of fictitious persons, such as *Tom (T) is older than Dick (D), Dick* *is older than Harry (H), Harry is older than Chris (C)*, … etc., participants respond to later test queries (e.g., *who is the older?*) about person pairs of wider distances on that T>D>H>C order (e.g., T-C) more quickly, and with greater accuracy, than about narrower distances (e.g., D-H, Potts, 1972, 1974; Smith & Foos, 1975; Pohl & Schumacher, 1991). This "symbolic distance effect" (SDE), suggests a spatial representation of the order T > D >H > C etc. constructed during learning (Leth-Steensen & Marley, 2000). Several authors have proposed that wider distances may be more discriminable than narrower distances (Holyoak & Patterson, 1981; Huttenlocher, 1968). Although tthe SDE may not necessarily rely on spatial representation (Hintzman, 1986; see also Leth-Steensen & Marley, 2000), research provides evidence of spatial involvement in such tasks (von Hecker et al., 2016, 2019; von Hecker & Klauer, 2021).

The faster speed and greater accuracy in processing elements from wider conceptual distances compared to narrower distances, can be taken as a proxy for subjectively experienced difficulty, therefore, as proxy for conceptual fluency (Wänke, 2013). As standard in the fluency literature, we assume that quicker responses indicate more subjective fluency (Winkielman et al., 2006; see Discussion). The involvement of fluency in SDE is suggested by brain imaging studies on transitive reasoning that found differences in activation in prefrontal and parietal cortex areas known to be involved in spatial processing (Acuna et al., 2002; Christoff et al.,2001; Hinton et al., 2010; van Opstal et al., 2009; Zalesak & Heckers, 2009): Test queries were easier on wider than narrower distances, and participants indicated they tried to form a mental chain to solve the task. In sum, research suggests that wider conceptual distances between pairs of matched items is associated with greater fluency than narrower distances.

1.4. Predictions

We assume that participants experience more fluency when processing information about order (e.g., in *age*, *frequency*, etc.) within a pair of wide than narrow distance, corresponding to more positive affect with wide distances, resulting in more liking for individual stimuli from wide than narrow pairs.

Notably, identifying the dominant (e.g., older, taller) element in a pair taps into the spatial order representation that generates the difficulty differential, which is therefore self-induced during reasoning. Thus, fluency does not stem from an isolated stimulus or any external context but is the experience of processing an order information about two mental elements, depending on all stimuli along the dimension. Given the above assumption, when learning and processing T>D>H>C order, participants should develop more positive responses towards T and C as compared to D and H.

As argued earlier, here we are interested in fluency and preferences that derive from the *configuration* between stimuli within a mental model, and not any other distinguishing attributes. Therefore we first test for SDE in all experiments to confirm that greater fluency corresponds with greater ordinal distance between comparison pairs. However, note that participants might also conflate preferences with "order dominance" (see von Hecker et al., 2016, 2019). For example, participants may prefer a dominant stimulus on the age dimension (oldest, or least old). This is especially possible with unfamiliar, arbitrary, neutral stimuli which lack more obvious cues for their liking. If so, participants might take the learned order relation as proxy for generating their liking judgment which has been termed “metaphorical blending” (Coulson & Oakley, 2005; Fauconnier & Turner, 1998). Casasanto (2009) illustrates this: “Linguistic expressions like ‘the prime example’ conflate primacy with goodness (i.e., this phrase can mean the first example, the best example, or both). Speakers of languages like English may be predisposed to consider the leftmost item to be the first and therefore the best.” (p. 362). Under the blending hypothesis, higher liking is expected for stimuli closer to the maximum than to the minimum. We test this process by comparing the liking between the two elements of any pair, independent of fluency predictions, based on closeness to the maximum (e.g., the *oldest* when the comparator is *older*) versus minimum (the *least old*).

Because fluency effects are usually small (see Winkielman & Cacioppo, 2001; Winkielman et al., 2003), their detection in the present research could be severely compromised by metaphorical blending. However, there are ways to isolate them. Consider a learned sequence A > B > C > D > E > F > G > H, with maximum at A (e.g., “oldest”). According to the fluency hypothesis, liking for stimuli A and H (wide distance – therefore easy) should be greater than liking for stimuli D and E (narrow distance – therefore difficult). Metaphorical blending predicts the same as fluency for stimuli A vs. D, that is, it predicts that A should be liked better than D, however predicts the opposite for stimuli E and H (E should be liked better than H). Therefore, we adopt a statistical strategy: Our statistical models must show independent, significant evidence for the *distance* effect (fluency), even in the presence of a significant *orientation* effect (metaphorical blending), in order to count as evidence in support of the fluency hypothesis. Conversely, if a data pattern can be exclusively explained by the metaphorical blending hypothesis, the fluency factor should not exhibit a significant effect.

1.5. Overview

The experiments reported here follow the same basic methodology (Leth-Steensen & Marley, 2000; Potts, 1972, 1974; Smith & Foos, 1975; Pohl & Schumacher, 1991; Sedek & von Hecker, 2004; von Hecker et al., 2016). In a learning phase, all possible pair combinations of an even number of stimuli (e.g., 8 in Experiment 1) are presented in a self-paced random sequence. Each pair represents a comparison, for example S_1 is *older* than S_2, etc., such that across all presentations a transitive rank order between S_1, S_2, …, S_k can be mentally constructed. We assume that this way, an analog, spatial mental model will be constructed along a hypothetical dimension (e.g., “age”) on which wider pairs are easier to discriminate than narrower pairs. A test phase immediately follows, except for Experiment 5 (see below). In the test phase, upon seeing a pair, participants press a marked key (“b” or “n”) on the side of the dominant, for example, “older” element. Crucially, each test stimulus can only be experienced in the context of the same difficulty level. For example, assuming a rank order S_1, … S_8, with S_1 as *oldest*, only pairs S_1S_8, S_2S_7, S_3S_6, and S_4S_5 were queried. Thus, a participant should experience the easiest (most fluent) processing for S_1 and S_8, “less easy” for S_2 and S_7, “hard” for S_3 and S_6, and “hardest” for S_4 and S_5. In the final phase (except for Experiment 5) single elements are presented to be evaluated one by one, selected only from the hardest and easiest pairs, that is, S1 and S8 (easiest) as well as S4, and S5 (hardest).

We expect stimuli to be rated more positively when associated with more fluency. Experiment 1 uses unfamiliar ideographs. Experiment 2 uses non-words, Experiment 3 addresses a non-spatial alternative explanation. Experiment 4 is a high-powered replication of Experiment 1, whereas Experiment 5 tests the possibility that differences in liking may already be created during the learning phase. In the Appendix, we report an experiment yielding only marginal results.

We planned conservative sample sizes for Experiments 1, 2 and 5 to detect typical effects (e.g., Reber et al. 1998, approx. $dz = .25$), N=37 (Experiment 1), N=42 (Experiment 2), and N = 37 (Experiment 5). With this, we obtained effect sizes around $dz = .20$, indicating a small effect. In Experiments 3 and 4 we ran high-powered replications of Experiment 1. Data and R scripts for analyses can be accessed at

https://osf.io/b4p38/?view_only=f1ee575d66d743c3978e565f4d201505

2. Experiment 1: The Relational Fluency Effect

In a first experiment, four sets of eight unfamiliar ideographs were chosen as to-be-ordered stimuli. We expected higher accuracy and faster correct responding to wider pairs of ideographs, as well as more positive evaluations of elements from wider as compared to narrower pairs.

2.1. Method

2.1.1. Participants

Thirty-seven undergraduate students from Cardiff University, School of Psychology (31 female, 6 male, mean age = 20.4 years), all with English-spoken backgrounds, took part in the experiment against course credit.

2.1.2. Material and procedure

Participants completed the task in front of a 22-inch screen, being asked to memorize various rank relations within unfamiliar letters. Instructions continued that some of the letters had been found to be older, or more frequently used, than others. For each participant, these comparators were randomly assigned to the four letter sets (2 and 2).

The experiment consisted of four blocks of letters from Chinese, Georgian, Konkani, and Tigrinya (presumably unfamiliar to our students with English-spoken background). From each alphabet (block), eight letters were chosen. Each block consisted of a learning, a testing, and a rating phase. In each trial of the *learning phase*, two letters were presented side by side, one declared as “older”, or “more frequently used”. Participants were asked to memorize the pairwise relations, pressing the space bar to switch from pair to pair (self-paced). All 28 possible pairs of letters were presented twice in a random sequence (56 trials). All possible pairs were presented in the first 28 as well as in the last 28 learning trials, no pair immediately repeating in the sequence. In the following *testing phase*, four pairs representing the four distance levels were randomly presented, that is, S_1S_8, S_2S_7, S_3S_6, and S_4S_5. Participants were asked to decide as quickly and accurately as possible which of the two letters was older, or more frequently used. In the final, *rating phase*, single letters were presented to be rated one by one, selected only from the hardest and easiest pairs, that is, S_1 and S_8 (easiest) as well as S_4, and S_5 (hardest). These four *single* letters were each rated twice, consecutively for each letter, in a random sequence, on two 7-point scales ranging from 1 (*not at all*) to 7 (*a lot*): "How much do you like me?" and "How much do you want me on a mug?"

The order of the blocks was random. Participants completed a short distraction task between two blocks. After all procedures (lasting 20-25 minutes) participants were debriefed.

2.2. Results

For an overview of our approach to data analysis, and for all results concerning the SDE replication, see Supplement, Appendix E. All experiments yielded an SDE (accuracies and latencies). As substantially correlated (r=.60) the two preference questions were averaged. The final model contained fixed effects for pair distance (4/5, 1/8), ideograph style, orientation (towards maximum vs. minimum), and the interactions (see Appendix C). Pair distance revealed, *F*(1,36) = 4.57; *p* = .03, *dz* = .20, that ideographs were preferred more (*t(988)* = -2.44; *p* = .014) within pairs of type 1/8 (*M* = 3.57, *SD*=1.46) than within pairs of type 4/5 (*M* = 3.36, *SD*=1.45).

Pair distance and orientation interacted marginally significant, *F*(1,988) = 3.52; *p* = .06, see Figure 1, showing for outer pairs, participants liked stimuli closer to the maximum more than those closer to the minimum (*t(74.4)* = -2.00; *p* = .04). The same did not hold for inner pairs (*t(74.4)* = .11; *p* = .91). Response times for a stimulus (as inner- vs. outer) significantly predicted the preference for it, *F*(1,68.91) = 6.21; *p* = .02, β = -.22.

2.3. Discussion

Experiment 1 revealed a source of fluency, namely, self-generated difficulty levels resulting from transitive reasoning, presumably resulting in an spatial representation, associated with differential liking of the stimuli involved. No prior knowledge or external information could influence the task. Participants liked ideographs from wide more than from narrow distances. An SDE (Leth-Steensen & Marley, 2000; von Hecker et al., 2016) was confirmed. Shorter latencies during the test phase, indicating easier processing, were associated with greater liking. Influences from stimulus characteristics were ruled out by randomly allocating ideographs to order positions for each participant.

The blending hypothesis (Casasanto, 2009; Coulson & Oakley, 2005; Fauconnier & Turner, 1998) was supported for outer pairs, not inner pairs. In the absence of more salient cues, participants presumably used the dimension (*older* or and *more frequently used than*) as proxy or a cue for liking, though only at wider pair distances.

3. Experiment 2: Replication with Non-Words

Our argument that difficulty levels are self-generated via mental model construction is not tied to particular modalities of perception, or stimulus types. Therefore we selected verbal stimuli for a second test. Different from Experiment 1, linear order construction here is likely to be based on verbal (or phonetic) rehearsal. As similarity and dissimilarity perceptions within sets of non-words have been shown to be driven by phonetic characteristics of non-words (Hahn & Bailey, 2005), the present experiment taps into a different rehearsal modality than Experiment 1. Still, non-words can be deemed plausible objects for liking judgments as well as graphic designs (ideographs). Explicit liking for non-words has been shown to be influenced by the valence of experiences associated with these same words (Schmidt & de Houwer, 2012). Therefore, we expect that self-generated fluency derived from transitive reasoning about non-words will influence explicit liking of the same stimuli.

3.1. Method

3.1.1. Participants

Forty-two undergraduate students from Cardiff University, School of Psychology (36 female, 6 male, mean age = 18.9 years), all with English-spoken backgrounds, took part in the experiment against course credit.

3.1.2. Material and procedure

Thirty-two non-words were generated from materials used by Bailey & Hahn (2001) in a study on the wordlike-ness of non-words (see Appendix B). The experiment consisted of four blocks, using four different sets of eight non-words. Procedures were the same as in Experiment 1 except participants being told that they would be learning rank relations between words from a fictitious language, some older or more frequently used than others. The two comparators were randomly assigned to the four non-word blocks (2 for each). At the end of each block, each non-word of the series was rated using the question: “How much do you like me?”.

Within blocks, the non-words within each set, as listed in Appendix B, were randomly assigned to rank positions within the to-be-learned order. Blocks were presented in a random sequence. The experiment lasted around 20-25 minutes.

3.2. Results

The final model contained fixed effects for pair distance (pair 4/5, pair 1/8), nonword list (4 lists), and orientation (maximum vs. minimum), comparator (“*older than*” vs. “*more frequent than*”), and the interactions (Appendix C). Pair distance was significant, $F(1,41.53) = 7.86$; $p = .008$; $dz = .26$, showing that non-words were liked more when coming from pairs of type 1/8 ($M = 3.74$, $SD=1.57$) than type 4/5 ($M = 3.34$, $SD=1.33$, $t(41.5) = -2.80$; $p = .007$), see Figure 2. List had a significant effect, $F(3,682.37) = 4.94$; $p = .002$, list-3-non-words being liked less ($M_{list3} = 3.27$) than the average of all others ($M_{lists124} = 3.62$), $t = 2.78$; $p = .009$. Type of comparator and pair distance interacted, $F(1,1070.86) = 5.29$; $p = .02$, the distance effect on liking being more pronounced for “more frequently used” ($M_{outer} = 3.77$,

SD_{outter} =1.11; M_{inner} = 3.24, SD_{inner} =.81) than for “older than” (M_{outer} = 3.69, SD_{outer} =.68; M_{inner} = 3.44, SD_{inner} =.89). Orientation was insignificant, $F(1,41) = 2.08$; $p = .16$ (no metaphoric blending), with no interactions. Latencies during testing did not predict liking ($F(1,65.98)$ =.37; $p = .55$).

3.3. Discussion

Accuracies were slightly lower than in Experiment 1. Participants may have found those stimuli relatively difficult due to phonetic rehearsal. There was more liking for non-words from wider pairs, as compared to narrower pairs on the hypothetical mental model. Participants probably experienced greater fluency with the former than the latter.

The distance effect on liking was more pronounced for comparator type “more frequent than” as compared to “older than”. Perhaps the meaning of “*more frequent than*” triggered more phonetic rehearsal than the meaning of “*older than*”, which could have accentuated the fluency experience for “*more frequent than*” in the test phase. As well, in this experiment, semantics of “frequency” could have been conducive to the creation of fluency (see e.g., Wänke, 2013). In summary, in a second study, tapping into a different stimulus modality than the first, the predicted association between experienced fluency and positive affect was replicated. However, liking was not predicted by response latencies. The metaphorical blending hypothesis received no support from this experiment.

4. Experiment 3 : Number of “Wins”

As mentioned above, the SDE, rather than spatial, could alternatively be the result different activation levels between the stimuli (Hintzman, 1986; Leth-Steensen & Marley, 2000). In this case, perceivers might just notice that in an ordered sequence S_1, S_2, S_3, etc., the maximum stimulus, S_1, “wins” all comparisons within presented pairs, whereas the minimum stimulus will not win any of them. Tallying the “number of wins” for each stimulus might therefore be a mechanism leading to an order representation. With corresponding activation levels for each ideograph, this representation might produce an SDE without space being involved. Research on Evaluative Conditioning has found that winning or losing comparisons within US-CS pairs did influence CS likeability (Unkelbach & Fiedler, 2016). The present experiment rules out "wins" to occur at all.

Secondly, we test the emergence of an SDE in presentation modalities that use either *spatial* (Experiment 3a) or *temporal* cues (Experiment 3b) for indicating dominance, addressing the assumption that the SDE originates from an abstract, modality-independent cognitive entity (Huttenlocher, 1968; Gevers, Reynvoet, & Fias, 2003; Knauff, 2013; von Hecker et al., 2016).

4.1. Method

4.1.1. Participants

One-hundred and two (Experiment 3a) as well as 101 (Experiment 3b) undergraduate students from the University of California, San Diego, Department of Psychology, all with English-spoken backgrounds, took part in the experiment against course credit (3a: 74 female, 28 male, mean age = 20.1 years; 3b: 74 female, 26 male, one preferred not to say, mean age = 20.3 years).

4.1.2. Materials and Procedure

Materials were identical to Experiment 1 except only six letters from each ideograph style were used in each of the four blocks. Procedures were identical to Experiment 1 except detailed below. In both experiments, only the question "How much do you like me?"was used. In both experiments, one third of participants did two cycles as described, a third did five cycles, the remaining third did eight cycles.

Experiment 3a (spatial learning cues). In each block, the six letters were presented in a sequence from left to right on the screen, with the first letter occupying the leftmost screen position, and each subsequent letter occupying a stepwise-scaled position further on the right, such that at presentation of the sixth letter, the rightmost position on the screen was reached. Presentation was self-paced. After presentation had started with the first letter, upon pressing the space bar that letter would disappear and the second letter would appear further to the right, and so on. Only “older” was used as comparator, and participants were instructed that in the sequence, any letter positioned *left* to another was to be considered “older” than the other.

Experiment 3b (temporal learning cues). In each block, the six letters were presented centrally on the screen, with the first letter appearing first, and each subsequent letter at the same central position in temporal order. Presentation was self-paced. After the presentation had started with the first letter, upon pressing the space bar, that letter would disappear and the second letter would appear, and so on until the last letter. Only “older” was used as comparator, and participants were instructed that in the sequence, any letter appearing *prior* to another was to be considered “older” than the other.

4.2. Results

Experiment 3a (spatial learning cues). The final model used for analysis contained fixed effects for pair distance (pair 3/4, pair 1/6), ideograph style (Chinese, Georgian, Konkani, and Tigrinya), orientation (towards the maximum vs. towards the minimum of the dimension), number of learning cycles (2, 5, 8), and the interaction of these factors (for its random effect structure see Appendix C). Learning cycles was not involved in any effect. Pair distance yielded a significant effect, $F(1,94.11) = 12.24$; $p < .001$, $dz = .14$, showing that ideographs were preferred more when they had been tested within pairs of type 1/6 ($M = 4.59$, $SD=1.80$) than when tested within pairs of type 3/4 ($M = 4.29$, $SD=1.61$, *t-ratio* = -3.49 ($df = 94.1$); $p < .001$), see Figure 3.

There was also a significant main effect for orientation, $F(1,94.83) = 5.15$; $p = .03$, indicating that stimuli closer to the maximum ($M = 4.55$, $SD=1.73$) were preferred to those closer to the minimum (*M* = 4.33, *SD*=1.69, *t-ratio* = 2.26 (*df* = 94.8); *p* = .03). Lastly, there was a significant interaction between pair distance and ideograph style, *F*(3,1175.45) = 2.55; *p* < .05, showing that the preference for ideographs as contained in pairs of type 1/6 over those in pairs 3/4 was more pronounced for Georgian and Konkani blocks (*p* = .006 and *p* = .007), as compared to Chinese and Tigrinya blocks (*p*s > .22). In a separate model, predicting preferences for the stimuli involved in inner and outer pairs by the response times to these stimuli, and participants as random factor, response times for a stimulus significantly predicted the preference for it, *F*(1,727) = 5.767; *p* = .02, *β* = -.12.

Experiment 3b (temporal learning cues).

The model with identical structure to the above was used for analysis (cf. Appendix C). Learning cycles was not involved in any effect. Pair distance yielded a significant effect, *F*(1,1248.82) = 11.90; *p* < .001, *dz* = .13, showing that ideographs were preferred more when they had been tested within pairs of type 1/6 (*M* = 4.49, *SD*=1.80) than when tested within pairs of type 3/4 (*M* = 4.20, *SD*=1.72, *t-ratio* = -3.45 (*df* = 1249); *p* < .001).

Orientation was associated with a significant main effect, *F*(1,1248.82) = 33.81; *p* < .001, indicating that stimuli closer to the maximum (*M* = 4.59, *SD*=1.72) were preferred to those closer to the minimum (*M* = 4.10, *SD*=1.77, *t-ratio* = 5.81 (*df* = 1249); *p* < .001). There were no more significant effects. In a separate model, predicting preferences for the stimuli involved in inner and outer pairs by the response times to these stimuli, and participants as random factor, response times for a stimulus did not significantly predict the preference for it, *F*(1,694) = .64; *p* = .42, *β* = -.05.

4.3. Discussion

We addressed the alternative hypothesis that the emergence of the SDE could be due to differentials in activation levels between the stimuli (Hintzman, 1986; Leth-Steensen & Marley, 2000). During the learning phase the six ideographs in a block could not be associated with differential numbers of “wins”, that is, parings with other ideographs in which they would appear dominant. Using spatial or temporal primacy as learning cues for the generation of the order, we found strong SDE’s in terms of accuracy and latency patterns. Therefore, we conclude that a spatial representation of a linear order does spontaneously result even without the number of wins playing a role (for spatial order representations on the basis of temporal information see von Hecker et al., 2016, 2019). The present findings support the idea that self-generated fluency differentials in our task are presumably based on differentials in the processing of ideograph pairs which are part of spatial order representations.

Our main target effect replicated in both conditions: Participants showed greater liking for the ideographs that were part of the outer pairs in the learned order as compared to the ideographs that were part of the inner pairs. This is presumably because the former were inducing more fluency during the test phase. Again, the metaphorical blending hypothesis (see Casasanto, 2009; Coulson & Oakley, 2005; Fauconnier & Turner, 1998) was supported. Presumably, the preference dimension can be mapped onto dimensional dominance.

5. Experiment 4: High-powered Replication and Scale Reversal

We attempted a high-powered replication, using the same materials and methods as in Experiment 1, except participants were asked to rate each letter on a 7-point scale ranging from 1 (*a lot*) to 7 (*not at all*) according to the questions: “How much do you like me?” and “How much do you want me on a mug?” (scale reversal). The effect size obtained in this experiment was $dz = .22$. An a priori power analysis (Gpower 3.1.3., Faul, Erdfelder, Buchner, & Lang, 2009) for detecting a one-tailed difference between two dependent means (t-test) required a minimum sample size of $N = 156$. Two-hundred and three undergraduate students from the University of California, San Diego, Department of Psychology, all with English-spoken backgrounds, took part in the experiment against course credit. We did not track each participant's gender and age individually, but the mean age of the participant population is about 21 years, SD = 5 years, and is 70% female.

5.1. Results

The final model contained fixed effects for pair distance (outer pairs 1/8 of distance 7 versus inner pairs 4/5 of distance 1), ideograph style (Chinese, Georgian, Konkani, and Tigrinya), orientation (towards the maximum vs. towards the minimum of the dimension) and the interaction between these factors (see Appendix C). Pair distance showed, $F(1,202) = 5.91$; $p = .014$, $dz = .17$, that ideographs were liked more when tested in pairs of type 1/8 ($M = 4.13$, $SD=.85$) than in pairs of type 4/5 ($M = 4.26$, $SD=.82$; $z = 2.47$; $p = .014$), see Figure 4. Stimuli oriented towards the maximum ($M = 4.01$, $SD=1.65$) were liked better than those oriented towards the minimum of the dimension ($M = 4.37$, $SD=1.62$), $F(1,202) = 38.72$; $p < .001$, $dz = .13$), supporting the blending hypothesis. The interaction between both of these factors was also significant, $F(1,5268) = 45.55$; $p < .001$. Bonferroni-Holm-corrected simple effects revealed that for outer pairs, stimuli closer to the maximum were preferred to those closer to the minimum ($p < .001$). As found in Experiment 1, the same did not hold for inner pairs ($p = .224$). Participants liked outer stimuli more than inner stimuli when these stimuli were oriented towards the maximum ($p < .001$), but the difference was not significant when oriented towards the minimum of the dimension. There were no further significant effects.

For stimuli oriented towards the maximum only, response times significantly predicted the preference for it, $F(1,355.92) = 6.38$; $p = .02$, $\beta = .14$, that is, the shorter the response time, the more a stimulus was liked.

5.2. Discussion

Again, stimuli further apart on the hypothetical mental model were liked more than those closer to each other. Participants also metaphorically blended dominance on the dimension ("*older*", "*more frequently used*") with preference, liking stimuli more when oriented towards the dominant than the non-dominant end of the dimension. None of these effects alone can fully explain the obtained results, as effects are superimposed on each other. At the non-dominant end, with overall less liking there, compared to the dominant end, the difference between outer and inner stimuli was not significant, qualifying the predicted fluency effect. At the dominant end, that is, looking at stimuli for which the pattern clearly shows an outer- vs. inner-difference in liking, response latencies during the test phase predicted liking, which is in line with fluency assumptions. Thus, the blending hypothesis was not fully supported because more liking for the dominant element was observed for pairs of type 1/8 but not for type 4/5.

These results were obtained with reversed scale from 1 (*a lot*) to 7 (*not at all*), ruling out that in earlier experiments, higher liking ratings might have been driven by greater value on a relevant dimension (one large magnitude, i.e., distance, possibly implying another large magnitude, i.e., liking).

6. Experiment 5: Liking differentials immediately after learning?

Response times on the widest versus the narrowest pair predicted the liking differential between these two types of pairs in Experiments 1, 3a, and partly 4 (only for the pairs that were close to the maximum), but did not predict liking in Experiments 2 and 3b. Thus, there might be another, distinct source of fluency experiences with these stimuli, possibly unrelated to the experience participants have during the testing phase. Indeed, wider elements in the hierarchy, especially the end elements of the array, may be associated with easier processing already in the mental order construction phase, during learning. Earlier research has established that pairs towards the end extremes, and particularly the end elements themselves, are privileged for quick responding early on in the learning trials, as soon as they are being identified as end elements or close to them (Leth-Steensen & Marley, 2000; Potts, 1972, 1974; Shoben et al., 1989; Holyoak & Patterson, 1981). All these studies only had learning phases and did not use an additional testing phase analogous to ours (in which fluency was intentionally trained). We tested therefore whether a differential in liking between the widest and the narrowest pair could already be observed directly after learning, without having undergone the testing phase.

6.1. Method

6.1.1. Participants

Thirty-four undergraduate students from the University of California, San Diego, Department of Psychology, all with English-spoken backgrounds, took part in the experiment against course credit. We did not track each participant's gender and age individually, but the mean age of the participant population is about 21 years, SD = 5 years, and is 70% female.

6.1.2. Materials and Procedure

Materials and procedures were identical to Experiment 2, except now we had two groups: Participants in the R-T group rated the nonword stimuli directly after learning, that is before the testing phase. Participants in the T-R group rated the nonword stimuli only after having completed the testing phase.

6.2. Results

The final model contained fixed effects for sequence (R-T vs. T-R), pair distance (outer pairs 1/8 of distance 7 versus inner pairs 4/5 of distance 1), and orientation (towards the maximum vs. towards the minimum of the dimension) and the interaction between these factors (see Appendix C). Supporting our main hypothesis, pair distance showed, $F(1,472) = 5.19$; $p < .02$, $dz = .17$, that ideographs were liked more when tested in outer (wide) pairs of type 1/8 ($M = 4.08$, $SD=1.41$) than in inner (narrow) pairs of type 4/5 ($M = 3.84$, $SD=1.07$), see Figure 5. Stimuli oriented towards the maximum ($M = 4.13$, $SD=1.37$) were liked better than those oriented towards the minimum of the dimension ($M = 3.79$, $SD=1.11$), $F(1,32) = 4.77$; $p < .03$), supporting the blending hypothesis as well. The interaction between both of these factors was also significant, *F*(1,472) = 10.17; *p* = .002. Bonferroni-Holm-corrected simple effects revealed that for outer pairs, stimuli closer to the maximum were preferred to those closer to the minimum (*p* < .001). As found in Experiment 1, the same did not hold for inner pairs (*ns*). Participants liked outer stimuli more than inner stimuli when these stimuli were oriented towards the maximum (*p* < .001), but the difference was not significant when oriented towards the minimum of the dimension. There were no further significant effects, including the sequence order (R-T vs. T-R). Latencies during testing did not predict liking (*F*(1,503) =.00; *p* = .98).

6.3. Discussion

In this experiment, participants liked stimuli from outer pairs (1/8) more than those from inner pairs (4/5). This occurred whether or not participants had been exposed to training on pairs of different pair distance. We had taken training of the widest and narrowest pairs as a proxy for generating high versus low fluency in the testing phase. The present results however reveal that differential liking of these two types of pairs is not necessarily rooted in such kind of training, and is therefore not necessarily based on fluency as experienced during the test phase.

The learning phase may instead, and alternatively, generate fluency differentials in its own right. Extreme elements in the hierarchy, and in particular end points, can bestow constructional advantages that make it easier to process such elements and again may create fluency experiences associated with these elements (Leth-Steensen & Marley, 2000; Potts, 1972, 1974; Shoben et al., 1989; Holyoak & Patterson, 1981; see also von Hecker & Klauer, 2021). The idea is that during construction of a linear mental model about the rank hierarchy, the end elements can serve as “anchor points” that subsequently facilitate the recognition of maximum and minimum within an abstract dimension. The fact that response times during training predicted liking of the stimuli only in half of our experiments can be speculatively explained by the assumption that in some cases either of these sources of experienced fluency will be more predominant than the other when it comes to generate liking responses in the later rating phase.

7. Internal Meta-Analysis

To test whether the pair distance effect on liking was robust across all six experiments (N = 519), a random effect meta-analysis was conducted, using Cohen's *dz* as effect sizes (the results remained the same when a fixed effects model instead of a random effects model was assumed). The analysis was based on the formulas provided by Borenstein, Hedges, Higgins, and Rothstein (2009) as implemented in the R package "rmeta" (Lumley, 2015). The overall effect size was *dz* = .18, 95% CI [.09, .27], suggesting that the effect is small, but robust.

8. General Discussion

This research explored whether self-generated fluency, arising from an internal mental model, shapes evaluative judgments. We propose that learning and using the mental model creates differences in difficulty levels when processing its elements, which then results in differential liking of the elements. A key feature of this process is that it is self-generated. By this we mean that distances between the elements derive solely from the participant's own reasoning, integrating all piecemeal information into one mental model. As such, the novelty of our results lies in the fact that the variations in fluency experiences do not stem from any external or pre-existing information about the stimuli (see Alter & Oppenheimer, 2008, 2009), but from the order construction process in a participants' mind. Therefore we propose that this cognitive activity, which is initiated in the learning phase (see Experiment 5) and continuing in the test phase (Experiments 1-4), is the key source of subjective experiences of ease/difficulty and positive/negative affect. In order for participants to feel more positive about some items, it takes less effort with those items when first establishing the integrated array representation, and then less effort when later using this representation to decide about the relative position of these items.

For experiences of effort to emerge during learning and during testing with stimuli of different pair distance, we assume that the primary driving factor is the self-generated, spatial positioning of stimuli in terms of a linear mental model (von Hecker & Klauer, 2021). As often argued for such a representation, stimuli of wider distance may be better discriminable than narrower distances (Holyoak & Patterson, 1981; Huttenlocher, 1968; Leth-Steensen & Marley, 2000), such that the dominant element in a pair can be learned and later identified more easily and reliably. Experiment 5 suggests that differences in liking are established already in the learning phase. We attribute this effect to fluency again, because it is probably easier to master the end points in a hierarchy, as compared to stimuli in the middle.

Overall, the crucial effect of pair distance on liking was obtained for unfamiliar ideographs (Experiments 1, 3, 4, 6), and non-words (Experiment 2 and 5). An internal meta-analysis confirmed the overall significance of the effect across individual experiments. Consistent with the idea that processing pairs of varying distances generates differences in fluency and liking, response times in the testing phase significantly predicted liking responses in the rating phase. However, this was true for Experiments 1, 3a, 4, and 6, but not in the remaining experiments. The fact that such prediction was significant in just half of our empirical data made us consider, in the first place, the possibility that differences in liking between different elements might arise already in the learning phase, as explained above. Our partial explanation for why the response times in the testing phase are only sometimes predictive of liking ratings lies in the assumption that one of the sources for fluency differentials, that is, either the learning or the testing phase, will eventually play a more dominant role in determining liking in the rating phase. To spell out the determinants of which source of fluency (at learning or at testing) will prevail in a given situation will be a matter of future research. We will shortly return to discuss additional challenges with measuring fluency in this paradigm.

The current studies also offer partial support for the metaphoric blending hypothesis, according to which participants might conflate dimensional dominance with preference and then take the learned rank order as proxy for their liking order (Casasanto, 2009; Coulson & Oakley, 2005; Fauconnier & Turner, 1998). In those experiments that yielded statistical support for this hypothesis (1 partly, 3, 4, 5, 6 partly), the effects held for stimuli from wider, but not narrower, pair distance. Whilst there is, therefore, some reason to believe that the position relative to maximum within the learned order influences the generation of liking judgments, there is nevertheless a statistically independent contribution of the fluency factor.

The pair distance effect on liking cannot be explained by metaphorical association of wider distances with greater liking, as in Experiment 4 the rating scale was reversed such that greater liking was represented by smaller numbers on the scale, in which case we found again greater liking (as indicated by numerically smaller values) for stimuli from wider-distanced pairs.

It is also unlikely that participants like the distant items more only because they "correctly" solved them because we did not give them feedback on their responses. At the same time, we assume that a participant, in order to generate a liking response, may consider the experience of progress, rightness, or confidence when learning or using that item, without explicitly knowing whether they are right or wrong. We submit that the quality of these subjective experiences is covered by the broad notion of fluency (Fazendeiro et al., 2005; Reber et al., 1998; Topolinski et al., 2009; Whittlesea, 1993; Winkielman et al., 2015).

In terms of external validity, our project shares a particular burden of proof with other research on fluency, which is that the subjective experience of fluency as such is not directly measured. Fluency is only stipulated to have a quality of subjective experience. In some of our experiments we did observe that response latencies in the test phase predicted liking (Reber, Wurtz, & Zimmermann, 2004) of the same stimuli in the rating phase (Experiments 1, 3a, 4, and 6). Given that Experiments 3 and 4 in particular had sufficient power to detect reliable effects, we still suppose that shorter response latencies for high-fluent than low-fluent processing in the test phase, had an effect on liking in the mentioned experiments.

8.1. Superposition of metaphorical blending and fluency effects

Where we find at least partial support for blending (Experiments 1, 3, 4, 5 and 6) the pattern suggests that fluency and blending may have the same (positive) effect on the dominant end of the ordering whilst their effects might cancel out on the lower end (symmetric blending). Alternatively, metaphorical blending may only occur at the dominant but not the non-dominant end of the ordering (asymmetric blending). As yet, there is empirical support for asymmetric blending in studies (von Hecker et al., 2016, Experiments 4a and b) where rank orders were presented with the unmarked or marked label ("older than" vs. younger than"; see Hamilton & Deese, 1971). We found blending with unmarked ("older than") but not marked dimensional semantics ("younger than"). If the preference for elements from wide pairs over the elements from narrow pairs was entirely due to asymmetric blending, we would not obtain statistically independent contributions of "pair distance" in our analytic models, as opposed to the variance explained by "orientation". The fact that we consistently observe independent variance contributions of "pair distance" in the models, in the presence of "orientation" effects, suggests a case of superposition of one effect (blending) upon another (fluency). Note that we can predict the "orientation" effect on the grounds of asymmetric metaphorical blending.

8.2. Self-generated fluency

As discussed earlier, the present investigation is different from earlier approaches where fluency manipulations focused on external contexts or stimulus features, that is, factors outside the participant. The processing in our experiments is determined by the *relation in which the stimulus stands with other learned stimuli*, within an overall mental model that comprises all stimuli in relational terms. This model does not exist in the external world but is a mental construction, yielding a representation with spatial characteristics (Baranski & Petrusic, 1992; Huttenlocher, 1968; Leth-Steensen & Marley, 2000; Pohl & Schumacher, 1991; Potts, 1972, 1974; Smith & Foos, 1975)[1]. Experiment 5 has provided evidence suggesting that mental operations in the learning phase might already create differentials in effort and liking between the stimuli.

8.3. Other approaches to self-generated differences in experienced fluency

The research interest in fluency origins that are self-generated is, as such, not new. Accordingly, we will next discuss three such approaches with respect to a possible overlap with the present paradigm.

(1) Unkelbach (2006) used mental rotation in order to implement differences in experienced task fluency. The task involved "*same* / *different*" judgments on geometric shapes, matched against a comparison shape, requiring either a small (easy) or a large (difficult) rotation in mental space (Shepard & Metzler, 1971). Both Unkelbach's (2006) and our technique attempt to create differences in fluency experience by mental activity, but in different ways. In Unkelbach (2006) the *amount* of mental rotation is still externally determined by the graphical display of the rotated figures. In our paradigm no external constraints exist. Only pairwise rank statements (e.g., "A is older than B") are presented with no hint at the required length of the order chain, or at any spatial representation at all. Therefore, the emerging differences in item difficulty are entirely self-generated.

(2) The second paradigm to compare with ours is *ease of retrieval* (Schwarz, Bless, Strack, Klumpp, & Rittenauer-Schatka, 1991; Wänke, Bless, & Biller, 1996; Wänke & Hansen, 2015). Here, participants are, non-intuitively, more favorable toward an issue after retrieving just a *few* favorable arguments for it (easy), compared with successfully retrieving many favorable arguments (difficult). Both our method and theirs involve self-initiated mental processes. However, in the *ease-of-retrieval paradigm* the number of to-be-retrieved arguments is externally pre-set, so the amount of difference in experienced difficulty between the high- and the low-fluency condition is externally determined. In our method, the number of steps between two ideographs is not externally fixed, but self-generated through the mental construction of the order.

(3) Another related stream of research examines how liking is related to the mental representation of a category and its prototype (Ryali et al., 2020; Vogel et al., 2018, 2021. This research demonstrates the tendency for individuals to prefer a prototypical exemplar of a neutral category over atypical exemplars. This preference is partially due to the relative fluency of the prototype (Winkielman et al., 2006). Importantly, it emerges in situations where the prototype itself was never shown, but had to be formed on the basis of shown exemplars. As such, the prototype is self-generated. The common ground between this effect and ours is the assumption that a mental process can create an internal structure not presented during learning but nevertheless determining subsequent liking responses. Different from our research, the prototype is generated based on perceptual, automatic processes; for example, of storing summary images in memory (Posner & Keele, 1968, Rosch, 1978) or exemplars (Kruschke, 1992, see also Husaim & Cohen, 1981; Younger, 1990, for prototype abstraction in habituation paradigms and in early infants). In contrast, the processes involved in our paradigm are assumed to be consciously taken steps of transitive inference (in the learning phase), in order to establish a linear hierarchy in working memory.

8.4. Limitations and boundary conditions

The novelty of the present approach consists in a demonstration that self-generated differences in cognitive fluency can yield differences in evaluative response. We believe that this has a number of implications.

Boundary conditions. Variables that can determine fluency, such as exposure frequency, exposure duration and figure-ground contrast tend to have the strongest influence on evaluative judgments when the stimuli are novel, neutral and brief, thus minimizing the role of external sources of meaning and value (e.g., Bornstein & D'Agostino, 1992; Reber, Winkielman, & Schwarz, 1998). With more meaningful stimuli, the contribution of fluency to the evaluation is likely diminished. If a perceiver has well-established, or even overlearned, meaningful criteria available to generate a response, then fluency will have low priority or low relevance when generating a judgment (Schwarz, 1998). The small effect sizes observed for fluency manipulations suggests that fluency represents a decision criterion to be mainly used in situations where no ecologically more relevant or salient criterion is available (see Winkielman et al. 2003; Winkielman & Caccioppo, 2001). Fluency can be seen as a relatively weak, occasionally used fallback criterion in day-to-day affective experience and expression[2]. In the laboratory, the effects might show up most clearly when using neutral and novel stimuli, as they do not elicit pre-existing evaluative associations.

Limitation: Mediation. Basically, in our paper we argue that a spatial representation of a linear rank order (X) influences liking (Y), and that this is due to differences in fluency (M), as experienced vis-à-vis paired stimuli of different distance on the spatial dimension. We show evidence regarding X → Y, and previous fluency research suggests that M → Y and the accuracy/rt data on SDE speak for X → M. However, we do not strictly show that the effect of X → Y is due to M (fluency). At present, it remains unclear why, across all experiments, response times do not consistently predict liking judgments. It is possible that in the present paradigm, processing ease is not captured by response times as measured here. At any rate, our interpretation that fluency is responsible for the X → Y effect must have a caveat.

In future research, one might consider using subjective fluency measures, for example, subjective ratings of difficulty (Graf et al., 2018). One can then follow a correlative approach to evaluate its potential causal role (mediation). In the present paradigm, such subjective measures also have the advantage that they can be assessed for individual stimuli instead of pairs (the liking ratings are made on individual stimuli). Alternatively, one might manipulate naïve theories on what the subjective ease of processing implies for liking (Reber et al., 2004; Winkielman & Schwarz, 2001). If it was demonstrated that a different naïve theory of fluency (e.g., difficulty means positivity) eliminates or even reverses the effect of wider distances on liking, this would be strong evidence that fluency is at least part of the underlying process for how participants make liking judgments in this paradigm.

Conclusions

Cognitive fluency can be seen as a factor that can translate processing dynamics, perceptual or conceptual, into affective judgments. We submit that the construction of a linear mental model, under the assumption of its spatial characteristics (Huttenlocher, 1968; von Hecker et al., 2016), constitutes a source of fluency: Elements on a linear mental model that are wide apart can be easier discriminated than elements that are close to each other on the simulated dimension. During model construction, anchoring elements, such as stimuli at the minimum and the maximum of the hierarchy, make the mental operations easy. Elements that are more fluently learned and later more fluently discriminated are liked more than less fluent elements. Processing difficulty in this sense is entirely dependent on the *location of an object relative to another one* on a mentally simulated dimension. As far as this source of cognitive fluency can be influential in any given judgmental situation, we can say that there exists a factor based in reasoning alone (that is, with no external informational input about the stimuli) that will co-determine our liking.

The authors report there are no competing interests to declare.

9. References

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Footnotes

1

We do not, in the context of this paper, discuss the question to what extent spatial characteristics are a necessary element of forming such orders, or indeed, to what extent the

SDE needs spatial assumptions in order to be explained (but see Leth-Steensen & Marley, 2000 for such a discussion). Instead, we refer the reader to a series of studies in which we provided experimental evidence for spatial characteristics to be genuine and essential for the construction of linear orders such as used here (von Hecker et al., 2016, see also von Hecker & Klauer, 2021).

2

As a reviewer pointed out, another perspective on the obtained results would be to see our target effect as an indirect fluency effect: External experimental constraints make a decision easy/fluent versus difficult/dysfluent (i.e., asking participants to give liking ratings to stimuli of pair type A-F versus pair type C-D). In this perspective, it is not the fluency per se that is self-generated but only the internal model of the stimuli arrangement from which the level of fluency derives, depending on what decision is asked for. The interesting part is that the fluency of the decision is transferred or associated with the stimuli involved in the decision process. In antecipation of future research, one could assume that--if asked--participants also like the decision process A-F better than the decision process C-D. And liking of the decision process would correlate with liking of the stimulus. The interpretation as *indirect* fluency effect may additionally explain why the more *direct* blending effect is larger than the more indirect self-generated fluency effect investigated in the present research.

Table 1 **Experiment 1**, Accuracies and Response latencies by Pair distance.

	Pair distance							
	Pair 4/5		Pair 3/6		Pair 2/7		Pair 1/8	
Accuracy	.670	(.415)	.819	(.346)	.863	(.296)	.931	(.211)
Latency	1715	(1001)	1620	(1038)	1512	(866)	1371	(701)

Note. Accuracies are given in proportion of correct responses. Response latencies are given in milliseconds. Standard deviations are presented in brackets.

Table 2 **Experiment 2**, Accuracies and Response latencies by Pair distance.

Pair distance

	Pair 4/5		Pair 3/6		Pair 2/7		Pair 1/8	
Accuracy	.555	(.380)	.718	(.325)	.748	(.323)	.822	(.269)
Latency	1735	(920)	1800	(952)	1649	(869)	1591	(949)

Note. Accuracies are given in proportion of correct responses. Response latencies are given in milliseconds. Standard deviations are presented in brackets.

Table 3 **Experiments 3a and 3b**, Accuracies and Response latencies by Pair distance.

Experiment 3a.

	Pair 3/4		Pair 2/5		Pair 1/6	
Accuracy	.898	(.216)	.946	(.152)	.964	(.129)
Latency	2160	(1133)	1748	(645)	1469	(607)

Experiment 3b.

	Pair 3/4		Pair 2/5		Pair 1/6	
Accuracy	.948	(.124)	.979	(.074)	.978	(.079)
Latency	2077	(875)	1808	(902)	1437	(520)

Note. Accuracies are given in proportion of correct responses. Response latencies are given in milliseconds. Standard deviations are presented in brackets.

Table 4 **Experiment 4**, Accuracies and Response latencies by Pair distance.

	Pair distance							
	Pair 4/5		Pair 3/6		Pair 2/7		Pair 1/8	
Accuracy	.670	(.414)	.801	(.325)	.870	(.297)	.916	(.234)
Latency	1790	(913)	1694	(816)	1601	(766)	1491	(758)

Note. Accuracies are given in proportion of correct responses. Response latencies are given in milliseconds. Standard deviations are presented in brackets.

Table 5 **Experiment 5**, Accuracies and Response latencies by Pair distance.

	Pair distance							
	Pair 4/5		Pair 3/6		Pair 2/7		Pair 1/8	
Accuracy	.654	(.185)	.694	(.205)	.750	(.165)	.808	(.160)
Latency	1305	(728)	1329	(750)	1157	(697)	1187	(548)

Note. Accuracies are given in proportion of correct responses. Response latencies are given in milliseconds. Standard deviations are presented in brackets.

Figure 1 Caption: Experiment 1: Mean liking for stimuli from outer and inner test pairs, located closer to the maximum or the minimum of the dimension.

Legend: Preference (e.g., “how much do you like me?”) was judged on a scale from 1 (not at all) to 7 (very much). Error bars show 1 SE above and below the mean. Dark bars show liking for stimuli closer to the maximum, light bars closer to the minimum of the dimension.

Figure 2 Caption: Experiment 2: Mean liking for stimuli from outer and inner test pairs. Error bars show SE above and below the mean.

Figure 3 Caption: Experiment 3: Mean liking for stimuli from outer and inner test pairs, averaged across Experiments 3a and 3b. Error bars show SE above and below the mean.

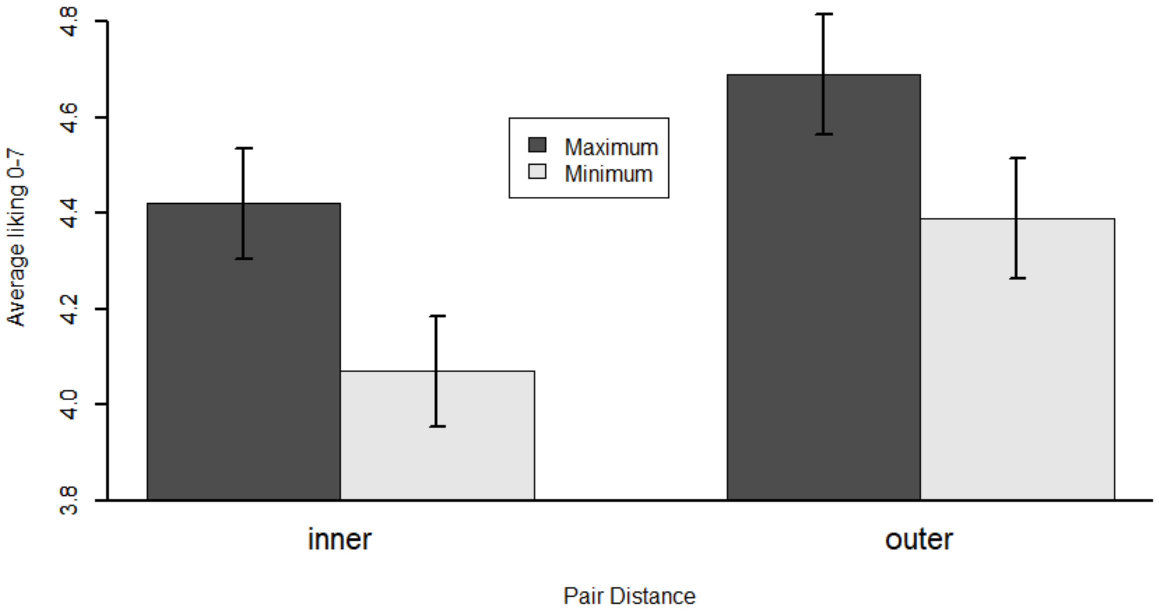


Figure 4 Caption: Experiment 4: Mean liking for stimuli from outer and inner test pairs. Error bars show SE above and below the mean.

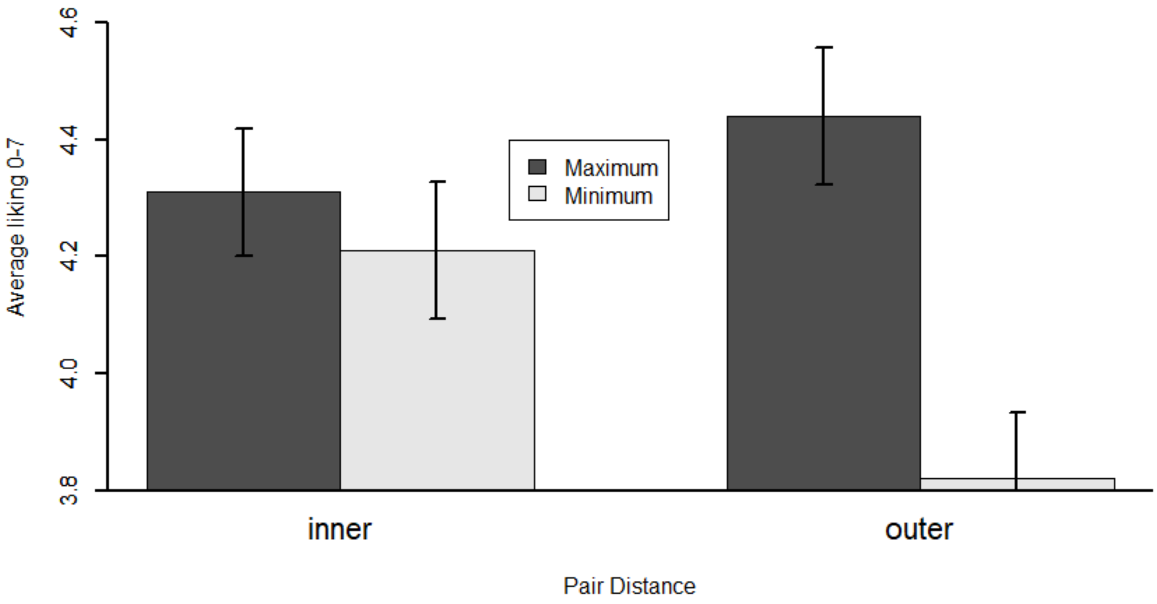
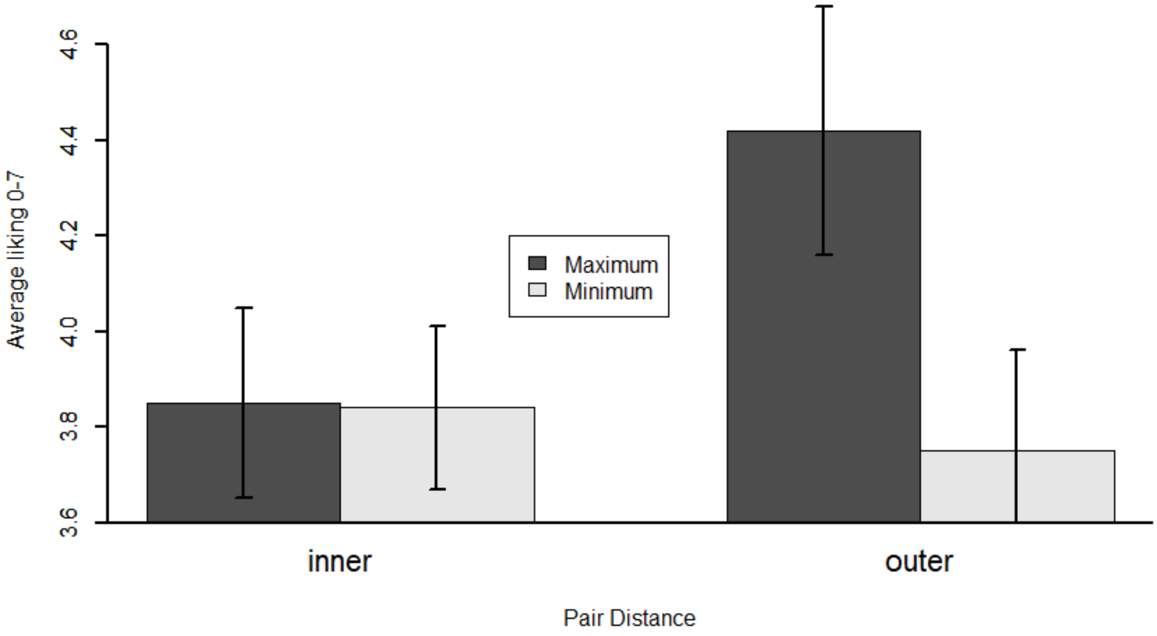


Figure 5 Caption: Experiment 5: Mean liking for stimuli from outer and inner test pairs. Error bars show SE above and below the mean.


Average liking 0-7
4.6
4.4
4.2
4.0
3.8
3.6
Maximum
Minimum
inner
outer
Pair Distance