Emotion


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# Affect From Mere Perception: Illusory Contour Perception Feels Good

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Can affect be evoked by mere perception? Earlier work on processing fluency, which manipulated the dynamics of a running perceptual process, has shown that efficient processing can indeed trigger positive affect. The present work introduces a novel route by not manipulating the dynamics of an ongoing perceptual process, but by blocking or allowing the whole process in the first place. We used illusory contour perception as one very basic such process. In 5 experiments (total $N = 422$), participants briefly ($\leq$100 ms) viewed stimuli that either allowed illusory contour perception, so-called Kanizsa shapes, or proximally identical control shapes that did not allow for this process to occur. Self-reported preference ratings (Experiments 1, 2, and 4) and facial muscle activity (Experiment 3) showed that participants consistently preferred Kanizsa over these control shapes. Moreover, even within Kanizsa shapes, those that most likely instigated illusory contour perception (i.e., those with the highest support ratio) were liked the most (Experiment 5). At the same time, Kanizsa stimuli with high support ratios were objectively and subjectively the most complex, rendering a processing fluency explanation of this preference unlikely. These findings inform theorizing in perception about affective properties of early perceptual processes that are independent from perceptual fluency and research on affect about the importance of basic perception as a source of affectivity.

*Keywords:* Gestalt, illusory contours, affect, Kanizsa illusion, early visual processing



Can affect be evoked by mere perception? Since the ability to determine whether a stimulus constitutes a threat or an opportunity for reward is an integral part of human survival, it is not surprising that humans are exceptionally good at determining the valence of stimuli in their environment (cf., e.g., Bargh, Chaiken, Raymond, & Hymes, 1996; LeDoux, 2000; Leventhal & Scherer, 1987; Morris, Öhman, & Dolan, 1998). However, in such cases evaluative features of the perceived stimuli evoke affect. But what about the perception of neutral stimuli? There is also a rich tradition of research on links between perceptual processing of neutral stimuli and affectivity, which dates back to Gustav Fechner's idea of bottom-up-driven aesthetic pleasure (Fechner, 1876), principles in Gestalt psychology (see, e.g., Koffka, 1935; Wertheimer, 1923), and is now investigated under the notion of *perceptual fluency* (for a review, see, Reber, Schwarz, & Winkielman, 2004).

Perceptual fluency refers to fast and efficient visual encoding of stimuli, which elicits positive affect that, in turn, is misattributed to an intrinsically neutral stimulus. Thus, a fluently processed neutral stimulus is evaluated more favorably than a disfluently processed neutral stimulus. Many properties increase perceptual fluency and hence can lead to a more positive evaluation of a stimulus (for an extensive review, see Reber et al., 2004), such as low complexity, high symmetry (Rhodes, Sumich, & Byatt, 1999), contrast, clarity, and prototypicality (Halberstadt, 2006; Winkielman, Halberstadt, Fazendeiro, & Catty, 2006), averageness (Halberstadt & Rhodes, 2000, 2003), but also the familiarity of the stimulus (e.g., Halberstadt, Rhodes, & Catty, 2003; Topolinski, 2012) or the perceiver's learning history with it (e.g., Goldstone, Medin, & Halberstadt, 1997; Halberstadt & Winkielman, 2014; Rhodes, Halberstadt, & Brajkovich, 2001; Rhodes, Halberstadt, Jeffery, & Palermo, 2005).

In this paper, we introduce a novel route by which perception itself can evoke affect, beyond perceptual fluency. Fluency research usually manipulates the ease with which a certain perceptual operation can be executed. Instead of manipulating *how* a process occurs, here, we rather manipulate *whether* a certain perceptual operation is executed or not in the first place. In this vein, the present studies continue and expand a recent approach exploring affective consequences of Gestalt completion (cf., Wertheimer, 1923) and visual disambiguation (cf., Long & Toppino, 2004) of possible and impossible Necker cubes (Necker, 1832). Experimentally enabling or disabling individuals to complete these basic early visual processes led to more or less positive

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affect, respectively (Topolinski, Erle, & Reber, 2015; for an earlier theoretical speculation on this, see Barrett & Bar, 2009).

In the present work, we focus on illusory contour perception. Illusory contour perception is a phenomenon where "illusory" contour edges are perceived although there actually is no change in luminance or color at a certain location. Although this phenomenon has been approached by many researchers and with differing methodologies (for a recent review, see, e.g., van Lier & Gerbino, 2015), the most well-known instance of illusory contour perception are Gaetano Kanizsa's geometric shapes (see, e.g., Kanizsa, 1955, 1976; for examples, see the second column of Figure 1). These shapes are constituted by a number of inducer elements (the black "pacmen" in Figure 1) that surround an area of some geometric shape. In Figure 1, the Kanizsa illusion[1] refers to the perception of a white shape over the black inducer elements and parts of the background. This illusory shape is furthermore imbued with additional properties (e.g., Coren, 1972; Watanabe & Oyama, 1988).

A lot of research investigated the underlying processes of illusory contour perception (Larsson et al., 1999; Mendola, Dale, Fischl, Liu, & Tootell, 1999; Wu et al., 2012). The process happens during very early visual processing in the V1/V2 occipital areas, the lateral occipital complex, the right fusiform gyrus, and the lateral occipital sulcus—as rapidly as 100 ms after stimulus presentation (cf., Seghier & Vuilleumier, 2006). The process is furthermore cognitively rather impenetrable (Keane, Lu, Papathomas, Silverstein, & Kellman, 2012; Keane, Mettler, Tsoi, & Kellman, 2011), potentially reflecting its phylogenetic (Nieder, 2002) and ontogenetic (Valenza, Leo, Gava, & Simion, 2006) precociousness.

Although other determinants such as the number and size of the inducing elements (Petry, Harbeck, Conway, & Levey, 1983; Siegel & Petry, 1991) or the retinal and real size of the displayed objects (Dumais & Bradley, 1976; but see Shipley & Kellman, 1992) have been discussed as contributing to the perception of illusory contours, its most important determinant certainly is the so-called *support ratio*. The support ratio is the ratio of the present contour length (i.e., the black edges) to the total length of the edges of the illusory figure (i.e., the black edges plus the white gap; cf., Shipley & Kellman, 1992). The higher this ratio, the more likely illusory contour perception is to happen (Shipley & Kellman, 1992).

Despite the fact that the procedural characteristics of illusory contour perception have received much attention, relatively little is known about how it relates to affectivity or semantics. A rare exception is the study by Bonaiuto, Giannini, and Bonaiuto (1991), who demonstrated that high-level semantic concepts can influence the perception of illusory contours. For instance, depicting human agents who perform a discernible action directed against an illusory shape increased the clarity of the perceived illusory contour. But to our knowledge, there exists no research on whether the process involves affectivity.

Here, we specifically predicted that the mere completion of the illusory contour perception process elicits positive affect. We addressed this question in five experiments. The first three experiments sought to show that Kanizsa shapes are preferred over control shapes with identical (proximal) perceptual properties. The last two experiments directly ruled out two indicators of fluency, familiarity and complexity, as alternative explanations for these effects.

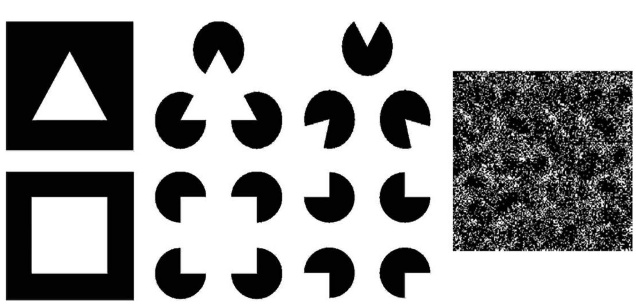

*Figure 1.* The target stimuli used in Experiments 1–4. (left) From left to right: triangles and squares featuring real, illusory, and no contours. (right) The masking stimulus.

## Data Analysis

We computed a priori power analyses based on the effects in prior studies (Experiments 1–3 in Topolinski et al., 2015) using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007). The sample size needed to achieve a power of $(1 - \beta) = .80$ was $N = 28$ for the self-report experiments and $N = 17$ for the Experiment 3. In most cases these thresholds were exceeded by a large margin and the median observed power of all significant focal tests was approximately $(1 - \beta) = 1$. No participant was excluded from any experiment and no other measures were recorded. All data and materials can be found at https://osf.io/y6umq/

## Experiment 1

In Experiment 1, the prediction that Kanizsa shapes would be preferred over control shapes because illusory contours can be interpolated only for Kanizsa stimuli was tested using self-reports of preference after very brief (25–100 ms) and postmasked stimulus presentation. Self-reports are an established measure of affective responses to nonevaluative stimuli (such as nonsense words, e.g., Topolinski & Bakhtiari, 2016; Topolinski, Boecker, Erle, Bakhtiari, & Pecher, 2017; Topolinski, Maschmann, Pecher, & Winkielman, 2014).

We implemented very short presentation times to prevent participants from basing their ratings on more elaborate conscious processes. With longer presentation times, it becomes more likely that participants generate hypotheses about the differences between the two stimulus categories that they translate into evaluative judgments. The very short presentation of the stimuli made it unlikely that participants engaged in such reasoning, thereby isolating the perceptual process as the only source of affectivity. At the same time, we ensured that even the briefest presentation timing of 25 ms was not subliminal, because this might have prevented the process of illusory contour perception in the first

[1] The geometric shape is an illusion only in a proximal sense in a two-dimensional display. Alternatively, the Kanizsa shapes in Figure 1 could be conceptualized as a three-dimensional configuration where a white triangle or square and three or four black pacmen or even full disks are displayed in front of a white background. In this case, the white shape would not be illusory but actually present.

place. In order to generalize the anticipated effect and to guarantee that presentation was supraliminal, at least in some cases, we also added two longer presentation times (50 ms and 100 ms).

## Method

**Participants.** Individuals ($N = 30$) from various professional backgrounds from Würzburg (18 female; mean age = 27, $SD$ = 10) with normal or corrected-to-normal vision participated for 12 euros.

**Materials and procedure.** Two Kanizsa and two control stimuli entailing the same visual entropy but no illusory contours were used (cf., Senkowski, Röttger, Grimm, Foxe, & Herrmann, 2005, p. 873), as well as a backward mask (see Figure 1 and https://osf.io/y6umq/).

The task was part of a larger experimental session involving other conceptually irrelevant tasks (assessments of empathic and spatial perspective-taking, Erle & Topolinski, 2015; rating solvability of anagrams, Topolinski, Bakhtiari, & Erle, 2016). Participants were tested in groups of up to two individuals on separate desks. They were told that the task assessed preferences for simple geometric stimuli that are very briefly presented and consequently masked. Participants sat at a distance of approximately 60 cm from the screen. The actual size in which the stimuli appeared on the screen was 10 cm × 10 cm. The support ratio of all Kanizsa shapes (except in Experiment 5, see below) was 0.66. Before the crucial test phase, all stimuli were presented to participants for 2,000 ms to familiarize them with the targets and to decrease their curiosity or suspiciousness on the briefly presented targets.

In each trial, first a plus sign was presented for 500 ms, followed by a blank screen for 500 ms. Then, the target stimulus was presented for 25 ms, 50 ms, or 100 ms, respectively, followed by a mask presented for 500 ms. After the mask, the question "How much did you like it?" appeared on the screen, and participants should type in a number ranging from 0 (*I do not like it at all*) to 10 (*I like it a lot*). An intertrial interval of 1,000 ms followed. Presentation time of the targets (25 ms, 50 ms, 100 ms) was manipulated in a block-wise manner, with sequence of blocks randomized across participants. Within each block, each target stimulus was presented three times; the sequence of stimuli within each block was randomized anew for each participant. There were three experimental blocks with 12 trials each, resulting in a total of 36 trials. The task took around 5 min.

## Results

A 2 (illusory contour: Kanizsa, control) × 2 (geometric shape: square, triangle) × 3 (presentation time: 25 ms, 50 ms, 100 ms) repeated-measures analysis of variance (ANOVA) was conducted. Since the sphericity assumption of the presentation time factor was violated, multivariate statistics are reported. Most importantly, there was a main effect of illusory contour, $F(1, 29) = 36.37$, $p < .001$, $\eta_p^2 = .56$. Kanizsa stimuli ($M = 5.45$, $SE = 0.34$) were preferred over control stimuli ($M = 4.69$, $SE = 0.31$), $d_z = 0.43$. Furthermore, there was a main effect of presentation time, $F(2, 28) = 8.38$, $p = .001$, $\eta_p^2 = .38$. Liking increased with increasing presentation times. Since there was no significant interaction, we were able to generalize the effect across presentation timings between 25 ms and 100 ms, indicating that potential boundary conditions for the observed affective consequences of illusory contour perception fall outside these presentation timings. The main effect of presentation time is conceptually irrelevant for the present research question but the preference for longer presentation times replicates the presentation time effect on liking found by Reber, Winkielman, and Schwarz (1998, Experiment 3). No other effect was significant, all $F$s $\leq 2.44$, $p$s $\geq .105$, $\eta_p^2$s $< .15$.

The preference for Kanizsa over control stimuli was present across presentation times (all $t$s $> 2.51$, all $p$s $\leq .018$, all $d_z$s $>$ 0.46) and for both triangles and squares (both $t$s $> 5.09$, both $p$s $<$ .001, both $d_z$s $> 0.93$). Even when looking at the design cells individually, the effect was present in all cases (all $t$s $> 2.88$, all $p$s $\leq .007$, all $d_z$s $> 0.52$), except for the 25 ms square cell, $t(29) = 1.91$, $p = .066$, $d_z = 0.35$ (Figure 2 and Table 1).

## Discussion

We presented Kanizsa stimuli featuring illusory contours and perceptually comparable control stimuli that prevented this additional contour interpolation process for only 25, 50, or 100 ms and postmasked these targets. We found higher spontaneous liking of Kanizsa compared with control stimuli reliably in each of the presentation timing conditions.

A possible effect of familiarity of the well-known Kanizsa stimuli compared with the rather unknown control stimuli seems unlikely since all experimental stimuli were presented to participants in the beginning of the session. Since this precaution might have been insufficient to override experiences with the well-known Kanizsa shapes, general familiarity of the Kanizsa stimuli will be addressed again in Experiment 4.

There are two other problems with the results of Experiment 1. First, no definition of "liking" was provided to the participants. Since it is unclear whether all participants interpreted and used the scale in the same way, we can conclude that participants rated Kanizsa shapes as more pleasant than control shapes, but not necessarily as pleasant. This limits the interpretability of our results in terms of absolute positive affect. Second, although we tried to combat this tendency using very short presentation times, it is possible that participants inferred from the presence of two distinguishable categories that the experimenter expects a difference between the ratings of them. In this case, the preference of Kanizsa shapes could be an arbitrary effect of experimental demand and no affective reaction. If this were the case, Kanizsa stimuli should be rated higher on any dimension and participants would, for instance, report higher "disliking" of the Kanizsa stimuli, too. Although there is ample evidence that rating scales are

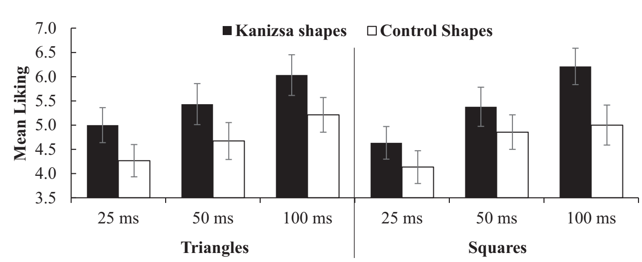


*Figure 2.* Mean liking of Experiment 1 by presentation time, geometric shape, and illusory contour. Error bars represent ±1 SEM.

Table 1
*Descriptive Statistics for Experiments 1, 2, and 4*

| Stimulus | Exp. 1 | | | Exp. 2 | | |
|---|---|---|---|---|---|---|
| | 25 ms | 50 ms | 100 ms | Liking | Disliking | Exp. 4 |
| Control square | 4.13 (1.85) | 4.86 (1.95) | 5.00 (2.26) | 4.67 (1.75) | 5.24 (1.86) | 4.55 (1.84) |
| Control triangle | 4.27 (1.83) | 4.67 (2.09) | 5.21 (1.96) | 4.68 (1.87) | 5.07 (1.83) | 4.55 (2.02) |
| Kanizsa square | 4.63 (1.84) | 5.38 (2.21) | 6.21 (2.05) | 6.32 (1.87) | 4.29 (2.04) | 5.99 (1.74) |
| Kanizsa triangle | 5.00 (1.98) | 5.43 (2.31) | 6.03 (2.30) | 6.18 (1.80) | 4.17 (2.16) | 6.04 (1.89) |
| Real square | | | | | | 6.14 (2.29) |
| Real triangle | | | | | | 6.38 (2.27) |
| Grand mean | | 5.07 (1.75) | | 5.46 (1.31) | 4.69 (1.39) | 5.61 (1.34) |

*Note.* Ratings were made on a scale from 0 to 10. The table displays the cell means and standard deviations in parentheses.



able to capture specific ratings of positive affect (see, e.g., Reber et al., 1998; Seamon, McKenna, & Binder, 1998; but see Mandler, Nakamura, & Van Zandt, 1987, for an incomplete dissociation between two rating scales), Experiment 2 additionally addressed these concerns empirically.

## Experiment 2

Experiment 2 replicated the 100 ms presentation timing condition of the first experiment. In addition to participants' liking of the stimuli, participants' disliking of the stimuli was assessed in a second separate block. If the results of Experiment 1 were due to genuine affective reactions toward the stimuli, the disliking ratings were expected to be lower for Kanizsa than control stimuli (see also Reber et al., 1998; Seamon et al., 1998).

### Method

**Participants.** In Experiment 2, $N = 53$ individuals from various professional backgrounds from Würzburg (39 female; mean age $= 27$, $SD = 8$) participated for 7 euros.

**Materials and procedure.** Experiment 2 was part of a larger experimental session involving other, conceptually irrelevant tasks. The procedural details were the same as in Experiment 1 with only six exceptions: (a) participants were tested in groups of up to six, (b) presentation time was always 100 ms, (c) each stimulus was presented four times per block, (d) the blank screen was presented for 1,000 ms, (e) there was no familiarization of the participants with the stimuli before the experiment, and (f) a disliking block was added to the experiment. Half of the participants completed the liking block first, whereas the other half completed the disliking block first. In the disliking block, the question, "How much did you dislike it?" appeared on the screen, and participants should type in a number ranging from 0 (*I do not dislike it at all*) to 10 (*I dislike it a lot*). Both blocks had 16 trials, resulting in a total of 32 trials. The task took around 5 min.

### Results

Data were subjected to a 2 (illusory contour: kanizsa, control; within-subjects) × 2 (geometric shape: square, triangle; within-subjects) × 2 (rating-scale label: liking, disliking; within-subjects) × 2 (block order: liking first, disliking first; between-subjects) mixed-models ANOVA which found a conceptually irrelevant main effect of rating-scale label, $F(1, 51) = 7.71$, $p = .008$, $\eta_p^2 = .13$. Liking ratings ($M = 5.46$, $SE = 0.18$) were overall higher than disliking ratings ($M = 4.69$, $SE = 0.19$), $d_z = 0.39$. Most importantly, there was a significant interaction of illusory contour and rating-scale label, $F(1, 51) = 19.92$, $p < .001$, $\eta_p^2 = .28$. Compared with the control stimuli, liking was higher for Kanizsa stimuli, $t(52) = 5.13$, $p < .001$, $d_z = 0.71$; but disliking was lower for them, $t(52) = -2.63$, $p = .011$, $d_z = 0.36$ (Figure 3 and Table 1). No other effect was significant, all $F$s $< 3.59$, all $p$s $\geq .064$.

### Discussion

These results replicate and extend the findings of Experiment 1 and convincingly demonstrate that the observed effects are genuine affective reactions to the stimuli rather than biased interpretations of the scale (see also, Reber et al., 1998; Seamon et al., 1998). However, it is still possible that the observed differences were not due to the completion of an early perceptual process, but rather due to participants' insight that there are two different categories that must be evaluated differently. Although it is unclear why this would necessarily lead to a preference for the Kanizsa shapes, we conducted an additional experiment measuring facial electromyography (fEMG) instead of self-reported liking (or disliking) to conclusively rule out any experimental demand and to further corroborate the results of Experiments 1 and 2. On top of this, based on the results of Experiments 1 and 2 we can, strictly speaking, only conclude that illusory contours are relatively more pleasant (and less unpleasant) than the absence of contours, but not that they are pleasant in an absolute sense. Using fEMG allows for

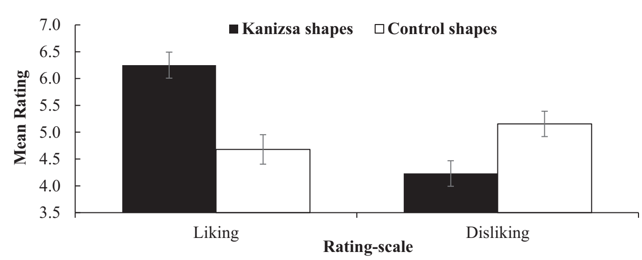


*Figure 3.* Mean liking and disliking of Experiment 2 for Kanizsa and control shapes. Error bars represent ±1 SEM.

such a conclusion, because fEMG introduces a baseline against which muscle activity is compared. Finally, fEMG allows us to look at the time course of affective changes during illusory contour perception.

## Experiment 3

In this experiment, participants passively viewed the same stimuli as in Experiment 1 for 25 ms, preceded and followed by a masking stimulus, while the activity of their M. zygomaticus major as an indicator of positive affect (Winkielman & Cacioppo, 2001), and their M. corrugator supercilii as an indicator of negative affect (Fridlund & Cacioppo, 1986) was recorded.

### Method

**Participants.** Individuals ($N$ = 60, 44 female, 15 male, one demographic data set lost due to technical issues; mean age = 25, $SD$ = 8) from various professional backgrounds from Würzburg with normal or corrected-to-normal vision participated for 12 euros.

**Materials and procedure.** We used the same stimuli, seating position, and actual stimulus size on the PC screen as in Experiment 1. Again, the later target stimuli were presented to participants for 2,000 ms each before the crucial test phase started. In each trial, first an exclamation mark appeared at the center of the screen (1,000 ms), followed by a blank screen (500 ms), a masking stimulus (100 ms), the target stimulus (25 ms), again a masking stimulus (100 ms), and finally a blank screen (8,000 ms). Since only the 25 ms presentation timing from Experiment 1 was realized, there was only one block in this Experiment. All four stimuli were presented three times, resulting in a total of 12 trials. The sequence of presentation was rerandomized anew for each participant. The task took 5 min.

**Facial EMG recording.** Facial EMG activity was assessed over the M. zygomaticus major and the M. corrugator supercilii on the left side of the face using bipolar placements of 13/7 mm Ag/AgCl surface-electrodes following the established protocol in psychological research (Fridlund & Cacioppo, 1986) and our earlier own research (Topolinski, 2012; Topolinski, Likowski, Weyers, & Strack, 2009; Topolinski, Lindner, & Freudenberg, 2014; Topolinski & Strack, 2015). The first 2,000 ms after stimulus onset were analyzed in epochs of 500 ms (cf., Winkielman & Cacioppo, 2001).

Impedances of all electrodes were reduced below 10 kΩ. Raw signals were measured with a V-Amp amplifier (Brain Productsl Inc.), digitalized by a 24-bit analog-to-digital converter, and stored with a sampling sequence of 100 Hz. 30 Hz, and 500 Hz cutoff filters and a 50 Hz notch filter were applied; data were rectified and transformed with a 125 ms moving average. The reported EMG data represent the average difference of all trials of one stimulus type to a 1,000 ms prestimulus baseline (i.e., the averaged activity over the 1,000 ms prior to the stimulus, as is standard in fEMG research).

### Results

The overall data structure in this experiment was quite complex as it had a 4 (epoch: 0–500 ms, 500–1,000 ms, 1,000–1,500 ms, 1,500–2,000 ms) × 2 (muscle: zygomaticus, corrugator) × 2 (illusory contour: kanizsa, control) × 2 (geometric shape: triangle, square) repeated-measures design. In congruence with the findings of our previous research, and to circumvent violations of the sphericity assumption in this complex repeated-measures design inherent to fEMG assessment, we formulated a specific plan for the data analysis.

First, zygomaticus activity should be higher for Kanizsa compared with control shapes, indicating that early perceptual processing is hedonically pleasant. This was tested by means of the main effect of illusory contour. This main effect has only one degree of freedom and thus is independent of violations of the sphericity assumption. Second, illusory contour perception is an instance where an early perceptual process runs to completion. In our prior research, we found that this leads to an increase of zygomaticus activity following the experimental (i.e., Kanizsa) stimuli over time, alongside no changes in activity following the control stimuli (cf., Topolinski et al., 2015). This effect was testable by means of trend analysis of the Illusory Contour × Epoch interaction. These trend analyses are recommended when the sphericity of repeated measures is violated (Tabachnick & Fidell, 2007, p. 330). Based on our previous results, we were not able to specify the exact order of the trend, so we Bonferroni adjusted the alpha level for this hypothesis. Since three orders of trends were tested, the alpha-level for this test was set to $p$ = .017. Finally, since only effects on the zygomaticus were observed in our previous research (Topolinski et al., 2015) and research on perceptual fluency (Reber et al., 2004; Winkielman & Cacioppo, 2001; Winkielman, Schwarz, Fazendeiro, & Reber, 2003), there was no hypothesis for the corrugator (corrugator analyses and data are available under https://osf.io/y6umq/, but are not reported in text).

Indeed, there was a significant main effect of illusory contour, $F(1, 59) = 4.46$, $p = .039$, $\eta_p^2 = .07$ (all other $F$s > 2.73, all other $p$s ≥ .051). Kanizsa stimuli led to higher (i.e., more positive) zygomaticus activity than the control stimuli, $d_z = 0.27$. Furthermore, trend analyses yielded a significant linear trend for the Illusory Contour × Epoch interaction, $F(1, 59) = 6.40$, $p = .014$, $\eta_p^2 = .10$. Separate trend analyses for the Kanizsa and control shapes yielded a significant linear, $F(1, 59) = 5.78$, $p = .019$, $\eta_p^2 = .09$, as well as a quadratic trend, $F(1, 59) = 4.00$, $p = .050$, $\eta_p^2 = .06$, for the former, compared with no trend at all for the latter, all $F$s < 2.03, all $p$s ≥ .160. Positive affect increased in a curvilinear fashion over time for the Kanizsa stimuli, but did not change for the control stimuli (Figure 4).

Finally, we were able to compare zygomaticus activity with the prestimulus baseline in order to assess whether the perception of

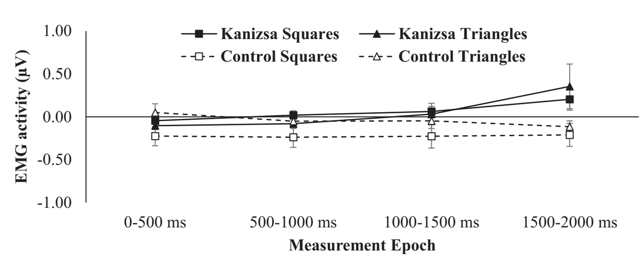


*Figure 4.* Zygomaticus EMG-activity of Experiment 3 over time for all stimulus types. Error bars represent ±1 SEM.

Kanizsa stimuli is indeed hedonically pleasant or only relatively more pleasant than the perception of control stimuli. Although zygomaticus activity increased after Kanizsa stimuli over time, it was not significantly different from zero at the last measurement, $t(59) = 1.96$, $p = .055$, $d = 0.25$. However, zygomaticus activity at the last measurement was significantly higher than at all prior measurements, all $t\text{s} > 2.32$, all $p\text{s} \leq .023$, all $d_z\text{s} > 0.30$. In this regard it is noteworthy that for the Kanizsa stimuli, zygomaticus activity during the first epoch was reliably below zero, $t(59) = -2.97$, $p = .004$, $d = 0.38$, which limited our ability to detect deviations in the opposite direction of the baseline.

## Discussion

Replicating the findings for self-reported liking in Experiments 1 and 2, we found higher zygomaticus activity (as an indicator of positive affect) after Kanizsa compared with control stimuli. Furthermore, fEMG assessment allows for conclusions about the directionality of an effect because it provides an evaluative baseline. Concerning this, a positive curvilinear trend for the Kanizsa stimuli, where an illusory contour was present, compared with no linear trend for the control stimuli, was found (see Figure 4). This indicates that the presence of illusory contours creates positive affect over time (cf., Topolinski et al., 2015; Experiment 3). Furthermore, Kanizsa stimuli seem to be only hedonically more pleasant than control stimuli, but not hedonically pleasant in absolute terms, as indicated by the nonsignificant difference to the prestimulus baseline even at the last measurement.

Having demonstrated that Kanizsa shapes are indeed preferred over perceptually matched control shapes, some open questions remain. Although we interpret these findings as a generalization of the idea that the completion of early perceptual processes is hedonically pleasant (cf., Topolinski et al., 2015), the previous results can alternatively be explained with fluency. First, although in Experiments 1 and 3 participants saw all stimuli before the experimental session in order to familiarize them with the materials; it is still possible that this was not sufficient to overcome the differences in familiarity between Kanizsa and control stimuli, because Kanizsa shapes are well-known icons that frequently feature in present-day pop culture. Higher familiarity increases perceptual fluency and attractiveness (see, e.g., Reber et al., 2004; Winkielman et al., 2003, 2006). Second, one could object that the experimental and the control stimuli differ in their complexity (cf., Reber et al., 2004; Winkielman et al., 2003, 2006). The more complex a stimulus is, the less fluent it can be perceived and consequently the less pleasant it is rated. The next two experiments went on to directly rule out stimulus familiarity (Experiment 4) and stimulus complexity (Experiment 5), two well-known sources of processing fluency, as alternative explanations of the results of Experiments 1–3.

# Experiment 4

Experiment 4 followed the general logic of Experiment 1, but additionally introduced real contours (a triangle and a square[2]; see Figure 1). Prior research has shown that repeated exposure to a stimulus increases its fluency and thus its liking (Zajonc, 1968). Since real contours are much more familiar than both Kanizsa and control stimuli, they should also be easier to process and be liked more than both other stimulus categories if familiarity were the sole causal explanation of the previously observed effects. However, in terms of the occurrence of illusory contour perception, real geometric contours are equivalent to the control shapes. Whereas real geometric shapes are already complete and thus logically cannot be completed any more, the arrangement of the inducer pacmen of the control shapes makes completion impossible in the first place. This difference notwithstanding, both stimuli are equivalent concerning the theoretically relevant mechanism, that is, in both cases an additional early perceptual process can never occur, whereas it can in the case of the Kanizsa stimuli. Therefore, if the previous effects were solely due to intrinsic positive affect of illusory contour perception, Kanizsa shapes should be preferred over the other two categories. Alternatively, it is, of course, also possible that early perceptual processes and familiarity produce positive affect independently of each other. In this case, both real contours and Kanizsa stimuli should be preferred over control stimuli, but there should be no difference in liking between them.

## Method

**Participants.** Students at the University of Würzburg ($N$ = 100; 49 female; mean age = 22, $SD$ = 3) were asked to participate in a 5-min psychological experiment in exchange for a candy bar.

**Materials and procedure.** The procedural details were the same as in Experiment 2 with only the following exceptions: (a) participants were tested in groups of up to eight individuals, (b) there was no disliking block, (c) also real geometric shapes were presented (see Figure 1), and (d) every stimulus was presented six times per block, resulting in 36 total trials.

**Pilot test.** A pilot study was conducted to demonstrate that participants are indeed more familiar with real geometric shapes than with both other stimulus categories and therefore have richer semantic associations with them. Participants simply viewed all six stimuli with an unconstrained time limit and answered the questions "How familiar are you with this stimulus?" and "Does the stimulus possess any meaning for you?" on scales from 0 (*Not at all*) to 10 (*Very much so*). Individuals ($N$ = 38; 21 female; mean age = 28, $SD$ = 9) from various professional backgrounds from Würzburg with normal or corrected-to-normal vision participated for 7 euros. The task took around 2 min.

The two ratings of each stimulus were combined into an index of familiarity,[3] which was then subjected to a 3 (contour type: implied, real, none) × 2 (geometric shape: square, triangle) repeated-measures ANOVA. Since the sphericity assumption of the contour type factor was violated, multivariate statistics are reported. This analysis yielded an irrelevant main effect of geometric shape (ratings were higher for squares, $M = 5.26$, $SE = 0.26$, than for triangles, $M = 4.59$, $SE = 0.23$), $F(1, 37) = 11.92$, $p = .001$, $\eta_p^2 = .24$. More importantly, there

[2] We later noticed that the real square, compared with the real triangle, entails "Ebenbreite" (see, e.g., Gerbino & Volcic, 2003; Metzger, 1953; Morinaga, 1941). However, we believe that it is not centrally relevant for the present results because (a) we did not find a difference in liking between real squares and triangles, and (b) such a difference would not have affected our familiarity hypothesis.

[3] Individual separate analyses for the two items yielded virtually the same result. For reasons of brevity, only the summary analysis is reported in text. Interested readers who want to redo these analyses are referred to https://osf.io/y6umq/

was a significant main effect of contour type, $F(2, 36) = 78.43$, $p < .001$, $\eta_p^2 = .81$, which is displayed alongside the main results of Experiment 4 in Figure 5. Real geometric shapes were rated as much more familiar than both other stimulus categories (both $t$s $> 9.69$, both $p$s $< .001$, both $d_z > 1.57$). Control and Kanizsa stimuli also differed significantly from each other, $t(37) = 2.65$, $p = .012$, $d_z = 0.43$. The difference in familiarity between these two categories, however, was significantly smaller than their differences to real contours (both $t$s $> 3.50$, both $p$s $\leq .001$, both $d_z > 0.56$). Based on a pure familiarity explanation and in the absence of any other ongoing affective process, real geometric shapes thus should be preferred over both other stimuli.

## Results

A 3 (contour type: implied, real, none) × 2 (geometric shape: square, triangle) repeated-measures ANOVA was conducted. Since the sphericity assumption of the contour type factor was violated, multivariate statistics are reported. This analysis only found a main effect of contour type, $F(2, 98) = 38.18$, $p < .001$, $\eta_p^2 = .44$. Real ($M = 6.26$, $SE = 0.21$) and illusory ($M = 6.01$, $SE = 0.17$) contours were preferred over control stimuli that did not feature any contour ($M = 4.55$, $SE = 0.18$); $t(99) = -5.91$, $p < .001$, $d_z = 0.59$ for real, and $t(99) = -8.78$, $p < .001$, $d_z = 0.88$ for illusory contours, respectively. Importantly, there was no significant difference between stimuli featuring real and illusory contours $t(99) = -1.10$, $p = .274$, $d_z = 0.11$, see Figure 5 and Table 1. All other effects were statistically not significant, all $F$s $< 1.09$, all $p$s $\geq .341$.

## Discussion

Experiment 4 shows that both Kanizsa and real contours are preferred over the control stimuli. There was, however, no significant difference between them, although real contours were, by far, the most familiar stimuli (cf., Figure 5). At the same time, only the illusory contours had the potential to elicit intrinsic positive affect of illusory contour perception. Thus, both familiarity and intrinsic positive affect of illusory contour perception are unlikely to be the sole explanation of the observed results, because based on pure familiarity real contours should be preferred by a large margin over both other stimulus types and, based on intrinsic affect from perception, Kanizsa shapes should be preferred over both other stimulus types.

There are two explanations for the absence of a difference between Kanizsa and real shapes. First, control stimuli could be disliked relative to the other two stimulus categories. However, as the data of Experiment 3 show, it is not the case that participants dislike control shapes, but rather that they like the Kanizsa shapes. Second, liking could be increased for real and Kanizsa shapes for different reasons. In line with the data from our pilot test, we believe that real contours were preferred over both other stimulus types because of their familiarity, while Kanizsa shapes were preferred over them due to the intrinsic positive affect elicited by illusory contour perception, which was only possible for Kanizsa stimuli. Thus, two sources (familiarity and intrinsic affect from perception) contributed positive affect independently, with one source benefiting real contours, while the other source benefited illusory contours. Future research could aim to explore this account further using fEMG, because the time course of a familiarity-based effect differs from the presently proposed mechanism. Whereas the present effects emerge only after an initial reduction in positive affect (cf., Experiment 3; see Figure 4), such a reduction in positive affect has not been reported for fluency effects on fEMG (see, e.g., Topolinski et al., 2009; Winkielman & Cacioppo, 2001; Winkielman et al., 2006).

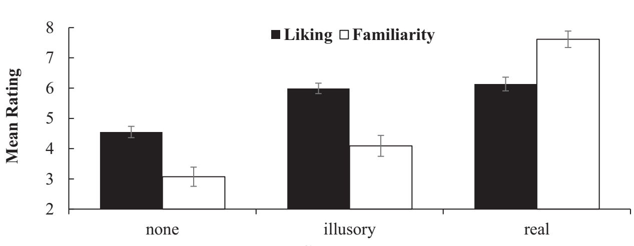


*Figure 5.* Mean familiarity of the pilot test and mean liking of Experiment 4 by contour type. Error bars represent ±1 SEM.

# Experiment 5

Experiment 5 aimed to show that (a) Kanizsa shapes that have a higher probability of evoking illusory contour perception are preferred over stimuli with a lower probability to do so, and (b) that these effects are independent of stimulus complexity. To this end, we manipulated the support ratio of the Kanizsa stimuli. The higher the support ratio of a stimulus, the higher is also the probability that illusory contour perception occurs, and hence, the more it should be liked. Statistically, we predicted a positive linear trend in our data.

Additionally, we aimed to rule out stimulus complexity as an alternative explanation of the previous results. Stimuli with high complexity are low in perceptual fluency and hence should be liked less (cf., e.g., Reber et al., 2004; Winkielman et al., 2006). While it is possible that control stimuli are more complex than Kanizsa stimuli, we anticipated that Kanizsa stimuli with different support ratios do not differ in terms of their complexity. To ensure this, we measured stimulus complexity in a pilot test of the stimuli used in Experiment 5. Anticipating constant stimulus complexity in our setup, any observed difference in liking in this experiment would not be attributable to perceptual fluency due to complexity. Furthermore, all Kanizsa shapes are virtually identical and hence do not differ with regard to familiarity. Finally, it is, in principle, possible that participants in Experiments 1–4 perceived the Kanizsa shapes that allow for illusory contour perception as the default whereas they experienced the control shapes as disruptions of this otherwise normal process. Such a disruption, of course, could function as a dysfluency signal. But since only Kanizsa shapes were presented in Experiment 5, the illusory contour perception process could be fully completed for *all* stimuli, which also disqualifies this alternative explanation for positive affect following the perception of Kanizsa shapes.

## Method

**Participants.** Students at the Universities of Cologne and Würzburg ($N = 76$; 50 female; mean age = 23, $SD = 6$) were asked to participate in a 5-min psychological experiment in exchange for a candy bar.

**Materials and procedure.** Experiment 5 was almost identical to the liking block of Experiment 2, with the only changes being that (a) 12 Kanizsa squares (adapted from Figure 1 in Shipley &

Kellman, 1992) were presented (b) three times (resulting in a total of 36 trials). The support ratio of these Kanizsa squares varied between 0.25 and 0.80 (all stimuli are available at https://osf.io/y6umq/). Stimuli were smaller than in the previous studies with an actual presentation size on the screen of 3 cm × 3 cm but otherwise comparable.

**Pilot test.** In order to ensure that the stimuli only differed regarding support ratio, and not regarding complexity, a pilot study was conducted. The study had the same methodology as Experiment 5 (see above), but asked for complexity ("How complex is the depicted stimulus?") instead of liking on a scale from 0 (*Not complex at all*) to 10 (*Very complex*). Individuals ($N$ = 65; 49 female; mean age = 27, $SD$ = 9) from various professional backgrounds from Würzburg with normal or corrected-to-normal vision participated for 5 euros.

The data were subjected to a repeated-measures ANOVA with support ratio as the only independent variable. Contrary to our prediction, the Kanizsa stimuli differed in complexity as indicated by a significant main effect, $F(11, 54) = 2.55$, $p = .011$, $\eta_p^2 = .34$. Post hoc analyses revealed that this main effect resembled a positive linear trend, $F(1, 64) = 17.39$, $p < .001$, $\eta_p^2 = .21$ (all other trends: $F$s $< 2.11$, all $p$s $\geq .152$): the higher the support ratio, the *more* complex the Kanizsa stimulus was rated (Figure 6).

Although we did not anticipate this difference in complexity, it is actually instrumental in determining the impact of processing fluency and early perceptual processing on preference ratings because it directly pits these accounts against each other. Based on our hypothesis, higher support ratios enhance the likelihood of illusory contour perception making evaluations of the Kanizsa stimuli more positive. In the pilot test it turned out that higher support ratios actually lead to higher perceived complexity, which means lower fluency (Reber et al., 2004), which should lead to lower liking if a fluency hypothesis would be true.

## Results

The data of Experiment 5 were subjected to a repeated-measures ANOVA with support ratio as the only independent variable. As hypothesized, there was a positive linear trend, $F(1, 75) = 14.10$, $p < .001$, $\eta_p^2 = .16$. The higher the support ratio, the higher the reported liking of the Kanizsa square. This trend was almost parallel to the trend observed for complexity in the pilot (see Figure 6 and Table 2). Furthermore, there was a strong positive correlation between complexity and liking: the more complex a stimulus was rated in the pilot (i.e., the *less* fluent), the more it was liked in Experiment 5, $r(10) = .93$, $p < .001$.

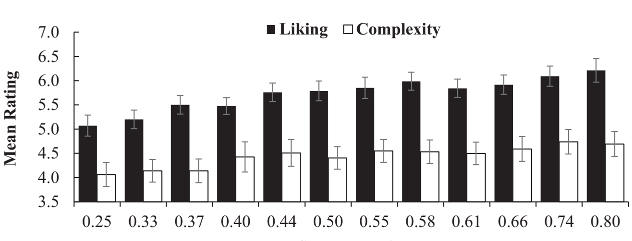


*Figure 6.* Mean complexity of the pilot test and mean liking of Experiment 5 by support ratio. Error bars represent ±1 SEM.

## Discussion

Taken together, the results of Experiment 5 conclusively rule out that subjective stimulus complexity accounts for positive affect toward Kanizsa stimuli, because the most complex stimuli were also liked the most. However, in some cases complexity does not necessarily imply lower fluency. For instance, in the domain of text comprehension, linguistic fluency can be enhanced by using a more complex syntactic structure. In this case, objective and subjective fluency would dissociate, as an objectively more complex sentence is subjectively easier to understand. In the present case, where only subjective complexity was assessed, such an alternative explanation of the results is unlikely. Nonetheless, we investigated the role of objective complexity for the present data using a common indicator of objective visual complexity in perception research, the zip-compressed file size of a picture (cf., e.g., Donderi, 2006; Landwehr, Labroo, & Herrmann, 2011). Complex pictures are less redundant than simple ones and therefore yield larger file sizes after compression.

In Experiment 5, files were generally larger for the high support ratios (the zip archives and the objective fluency data can be found at https://osf.io/y6umq/), indicating that Kanizsa stimuli with high support ratios are also objectively more complex. In addition, objective complexity was strongly positively correlated with subjective complexity, $r(10) = .77$, $p = .003$, and liking, $r(10) = .76$, $p = .004$, which speaks against the idea that the low objective complexity correlated with high subjective complexity and thus fluency. Therefore, this experiment demonstrates that enhancing the likelihood of illusory contour perception and not processing fluency increases positive affect toward a presented stimulus.

Note that, in principle, control and Kanizsa shapes of the previous experiments could still differ in their complexity. But the linear trends in Experiment 5 cannot be explained by this. Thus, even if complexity were involved in the previous results, early perceptual processing has affective consequences on top of such fluency mechanisms. This was also already evident in Experiment 1, where presentation time (a well-known fluency manipulation; cf., Reber et al., 1998) and the presence of an illusory contour had independent main effects on liking.

Table 2
*Descriptive Statistics for Experiment 5*

| Support ratio | Objective complexity | Subjective complexity | Liking |
|---|---|---|---|
| .25 | 1.02 | 4.06 (2.00) | 5.07 (1.90) |
| .33 | 1.13 | 4.14 (1.88) | 5.20 (1.67) |
| .37 | 1.13 | 4.14 (1.96) | 5.50 (1.67) |
| .40 | 1.37 | 4.43 (2.50) | 5.47 (1.51) |
| .44 | 1.24 | 4.51 (2.24) | 5.76 (1.66) |
| .50 | 1.38 | 4.41 (1.89) | 5.79 (1.76) |
| .55 | 1.34 | 4.55 (1.91) | 5.85 (1.91) |
| .58 | 1.40 | 4.53 (1.95) | 5.99 (1.62) |
| .61 | 1.89 | 4.50 (1.87) | 5.84 (1.66) |
| .66 | 1.43 | 4.59 (2.07) | 5.92 (1.75) |
| .74 | 1.64 | 4.74 (2.03) | 6.09 (1.82) |
| .80 | 1.71 | 4.69 (2.07) | 6.21 (2.12) |
| Grand mean | 1.39 (.25) | 4.44 (1.85) | 5.73 (1.37) |

*Note.* Ratings were made on a scale from 0 to 10. Objective complexity is measured in kilobytes. The table displays the cell means and standard deviations in parentheses.

## General Discussion

The present research contributes a novel finding to the already impressive body of literature on illusory contour perception (for a review, see van Lier & Gerbino, 2015), by demonstrating for the first time that the process can cause positive affect. Across five experiments, participants preferred Kanizsa shapes, which allow for illusory contour perception, over control shapes with proximally identical perceptual properties, but which prevented this early perceptual process. This preference was evident on self-reported preference ratings (Experiments 1, 2, and 4; Table 1) and during fEMG assessment (Experiment 3). Concerning directionality, the fEMG data show that zygomaticus activity increases after Kanizsa stimuli (see Figure 4), whereas for control stimuli zygomaticus activity does not change over time. In absolute terms, however, zygomaticus activity after Kanizsa stimuli was not more positive than the prestimulus baseline and, hence, Kanizsa stimuli are only relatively more pleasant than control stimuli, but not pleasant in an absolute sense. Furthermore, among Kanizsa shapes, those with the highest support ratio, that is, the highest likelihood for illusory contour perception to occur (cf., Shipley & Kellman, 1992), were preferred (Experiment 5; Table 2).

These findings describe a novel direct link between perceptual processing and affectivity that has not been considered in previous research on the affectivity of metacognitive signals (e.g., perceptual fluency; Reber et al., 2004). Experiments 4 and 5 even directly ruled out classical indicators of fluency (familiarity and complexity) as explanations for the observed effects. Experiment 5 also addressed another fluency-related concern that could be objected to in our previous research on Gestalt completion and visual disambiguation (Topolinski et al., 2015). In these previous studies, both Gestalt containing patterns and possible Necker cubes were always compared with stimuli that rendered the operation of an early perceptual process impossible. This could have led participants to interpret the control stimuli as disruptions of a processing sequence and this might have signaled dysfluency. Although a similar objection could be fielded against the first four present experiments, the last experiment included only stimuli that allow for the operation of illusory contour perception and therefore this concern does not apply anymore. Even under these conditions, stimuli that make the occurrence of an early perceptual process more likely (but that are more complex and thus less fluent) were preferred.

A related open question is whether the presently employed control stimuli are perceived as disruptions of a Kanizsa shape in the first place or rather as an independent arrangement of geometric shapes. Future research could capitalize on this ambiguity by framing them differently and assessing whether this affects affective responses toward them. For instance, the present control stimuli could be framed as an arrangement of “three pies” versus as an arrangement of inducer pacmen around a Kanizsa shape. By means of this, a perceived (non-)disruption of illusory contour perception could be experimentally manipulated using identical stimuli and the impact of this on affectivity could be assessed.

One limitation of the present research is that all stimuli were affectively neutral. Although matching all stimuli for their evaluative qualities facilitated the conclusion that perceptual processes per se account for the observed effects (cf., Larson, Aronoff, Sarinopoulos, & Zhu, 2009), it is an interesting question for further research whether the affective consequences of perceptual processes are also strong enough to change the evaluation of stimuli with preexisting evaluative qualities. Indeed, there exists some evidence supporting the notion that perception causes positive affect independent of stimulus valence, which would suggest an affirmative answer to this question (Chetverikov & Filippova, 2014). However, given that the perceptual system is especially concerned with the correct identification of such evaluative qualities (LeDoux, 2000; Morris et al., 1998), it is also possible that affective consequences of perceptual processes only play a role further down the line of stimulus evaluation checks (cf., Leventhal & Scherer, 1987). It is simply more important to identify a snake in the grass than to gain pleasure from its perception.

Another interesting question that remains open concerns the generalizability of the present findings along the temporal dimension of perceptual processes. All of the processes that we studied so far (Gestalt-completion, visual disambiguation, and illusory contour perception) occur very early on during the perceptual sequence, are rather impenetrable, happen without strong noetic awareness or insight into the results of the process, and exert their influence on affectivity rather immediately. In contrast to this, more complex and cognitively demanding processes, such as the analysis of an intricate piece of art are crucially dependent on awareness of the processing outcome. Here aesthetic pleasure stems from a moment of insight or understanding that dissolves the previous efforts associated with the processing experience (see, e.g., Chetverikov & Filippova, 2014; Chetverikov & Kristjánsson, 2016; Halberstadt & Hooton, 2008; Muth & Carbon, 2013; Topolinski & Reber, 2010). In these contexts, the process is not immediately pleasant but pleasantness is contingent on its outcome, which then serves as a (dis-)fluency signal (for similar notions, see Belke, Leder, Strobach, & Carbon, 2010; Graf & Landwehr, 2015).

Is it possible that early perceptual processes are just a miniature version of these more elaborate ones? Indeed, the present fEMG data might suggest this. As can be seen in Figure 4, the positive affect that stems from illusory completion is not so immediate after all. Initially after the perception of Kanizsa shapes, positive affect drops below its baseline and only later recuperates in a positive direction. This initial drop could represent the very brief phasic effort that is necessary to complete the illusory contour perception process. Only once the process has run to full completion, does it create a positive affective experience. This potentially suggests that also for early perceptual processes “insight” plays an important role and the only difference to more complex perceptual processes is the timeframe during which this happens.

## Conclusion

The present data are compatible with prior findings on affective consequences of early perceptual processing (Topolinski et al., 2015). Therefore, the notion that these processes are deeply connected to affectivity has now been demonstrated with three different processes, featuring very different stimulus materials, various presentation timings, and two different dependent measures. Overall, this paints a coherent picture of a robust direct link between perception and affect independent of processing fluency.

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