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When sounds look right and images sound correct: Cross-modal coherence enhances claims of pattern presence

Michał Ziembowicz [a], Andrzej Nowak [a], Piotr Winkielman [b,c,*]

[a] University of Warsaw, Institute for Social Studies, Poland
[b] University of California, Psychology Department, San Diego, United States
[c] University of Social Sciences and Humanities, Warsaw, Poland

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ABSTRACT

How do people decide whether a stimulus contains a pattern? One possibility is that they rely on a global, non-specific signal of coherence. Interestingly, this signal might reflect a combination of different stimulus sources. Consequently, the coherence of one stimulus might influence decisions about coherence of a second, unrelated stimulus. We explored this possibility in three experiments in which participants judged the presence of a pattern in targets from one sensory modality, while being exposed in the background to incidental coherent and incoherent stimuli in a different modality (visual → auditory, auditory → visual). Across all three experiments, using a variety of judgments, coherence of incidental background cross-modal patterns enhanced claims of pattern presence. These findings advance our understanding of how people judge order in the structured as well as in the unstructured world.

1. Introduction

Does hearing Bach harmonies make you claim patterns in the sky? Clearly, people sometimes "discover" organization in objectively unstructured material. This phenomenon occurs with various modalities and materials—i.e., visual (e.g., Rorschach figures, cloud faces, star constellations), auditory (e.g., ghost voices in noisy recordings, phone rings in the shower), or even with complex semantic stimuli (e.g., astrological signs, stock market trends). This tendency, also called *paraidolia* or *patternicity,* is sometimes viewed as reflecting our propensity for superstitious behaviors (Sagan, 1995; Shermer, 2008). Yet, normative claims are controversial since, in some environments, false alarms are less costly than misses (e.g., Foster & Kokko, 2009). Further, detecting non-existent patterns could be a necessary byproduct of the active nature of cognition (Wertheimer, 1922).

But how do people decide whether stimuli contain patterns? This central question has been addressed at multiple levels. Low-level perceptual mechanisms are important (e.g., Lewkowicz, 2010; Shams, 2010; Spence & Chen, 2012; Watanabe & Shimojo, 2001; Zhang et al., 2008). However, regularity judgments are also influenced at higher, decision-making stages by global variables. For example, positive affect and need for control increase claims of pattern presence (King, Burton, Hicks, & Drigotas, 2007; Whitson & Galinsky, 2008). Further, people detect semantic relations using fluency-based "intuitions" (Topolinski & Strack, 2009). Here, we explore the counterintuitive possibility that pattern judgments also depend on the regularity of incidental background stimuli, even from a different modality.

One type of regularity is coherence. Coherence can range from perceptual synchrony to logical consistency, but basically concerns conformance to a rule that integrates multiple elements (Thagard, 2000). Coherent stimuli

* Corresponding author. Address: Department of Psychology, University of California, San Diego, 9500 Gilman Drive, Mailcode 0109, La Jolla, CA 92093-0109, United States.

E-mail address: pwinkiel@ucsd.edu (P. Winkielman).

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can be visual figures, where parts conform to the rules of the 3-D world, or auditory sequences, where elements conform to the rules of pre-established grammar. Critically, though coherence can be an objective stimulus feature, decisions about its presence can be based on non-specific, subjective input. If so, coherence of one stimulus may influence decisions about coherence of another unrelated stimulus. This prediction is grounded in two theoretical perspectives – computational models postulating global network signals, and judgment models postulating non-specific experiences.

From a computational perspective, some connectionist models posit that networks generate non-specific signals about processing quality (Carpenter & Grossberg, 2003; Cleeremans & Dienes, 2008; Lewenstein & Nowak, 1989; Norman & O'Reilly, 2003; Zochowski, Lewenstein, & Nowak, 1994). These signals occur both at the larger network level (e.g., overall number of units changing state) and at the single-unit level (e.g., congruity of incoming inputs from other units) and can inform non-analytic decisions, such as familiarity or regularity. These signals can also regulate the network's own behavior, stopping the recognition process (preventing pattern discovery) when coherence is low and letting recognition continue when coherence is high (Rychwalska, Jabłoński, Żochowski, & Nowak 2005). Critically, the coherence signals can be relatively: (i) non-specific, with different forms of objective regularity generating a similar signal and (ii) free-floating, with signals not tightly bound to the original representation. Thus, coherence might transfer and influence decisions about unrelated stimuli.

From a behavioral perspective, several models highlight that decisions, including pattern judgments, rely on subjective experiences, such as a generalized sense of "ease", rightness", "integrality", or "familiarity" (Jacoby, Allan, Collins, & Larwill, 1988; Schwarz & Clore, 2007; Whittlesea, 2002). These experiences can be manipulated by priming, clarity, rhyme, or semantic predictability, and presumably reflect processing fluency (Alter & Oppenheimer, 2009; Topolinski & Reber, 2010).

Previous research has explored the role of experiences in cases when the target stimulus itself is made fluent or familiar. For example, target's processing was influenced via cross-modal, semantically related prime (Fazendeiro, Winkielman, Luo, & Lorah, 2005; Miller, Lloyd, & Westerman, 2008). However, if experiences are indeed non-specific, then experiences generated by unrelated background stimuli should also influence target judgments, because the "free-floating" experience can be misread as bearing on the target. This assumption fits with research on arousal and affect. For example, incidental factors (e.g., weather) influence unrelated judgments (e.g., life satisfaction), presumably because individuals base judgments on global mood (Schwarz & Clore, 2007). In short, both computational and behavioral perspectives suggest that coherence signals can be non-specific, combining inputs from dissimilar sources. Consequently, coherence of incidental background stimuli should influence decisions about coherence of unrelated target stimuli, even if they differ in the type of regularity and modality.

2. Present research

We report three experiments in which participants judged targets in one sensory modality (auditory or visual) while being exposed in the background to coherent and incoherent stimuli in a different modality. We predicted that background coherence would enhance claims of target regularity, resulting in both costs (false alarms) and benefits (hits). Finally, if coherence signals are indeed nonspecific, the coherence of the background and the foreground (target) should combine additively and occur regardless of which stimulus is the target or background.

In all experiments, we first established an independent regularity for our auditory stimuli (which serve as targets in Experiments 1 and 2, and backgrounds in Experiment 3). This minimizes any objective structural similarity between stimuli across modalities. Following the artificial grammar paradigm (Reber, 1967; Reber, 1993), each experiment started with a rule acquisition phase where participants passively learned a musical grammar. After that, participants were presented with target stimuli (half of which were actually regular) and asked to detect regularity. During this testing phase, incidental coherent or incoherent stimuli appeared in another modality. In Experiments 1 and 2, participants judged new auditory stimuli (new melodies, half of which were grammatical) accompanied by background visual stimuli (possible and impossible figures). In Experiment 3, participants judged visual patterns (possible or impossible figures) accompanied by background auditory stimuli (grammatical or ungrammatical melodies).

Finally, we explored the effect of cross-modal coherence with different types of subjective judgments: "regularity" (Experiment 1), "familiarity" (Experiment 2), and "possibility" (Experiment 3). We used claims of regularity and possibility as they directly reflect participants' beliefs about structure. We used familiarity to indirectly test participants' beliefs about pattern presence without making explicit the potential importance of the "regularity" dimension. Based on previous research, we expected parallel effects on regularity, possibility, and familiarity judgments (Kelley & Jacoby, 1998; Whittlesea, 2002).

3. Experiment 1

3.1. Participants and procedure

Twenty undergraduates participated for payment in a study presumably on "perception and memory". The experiment had a learning phase and a testing phase: In the passive learning phase (about 2.5 min), participants were told to "carefully listen to melodies". These 20 melodies were based on artificial grammar which defined possible note transitions (Reber & Sollberger, 2000). Each melody was composed of five notes: C(523 Hz), E(659 Hz), F(698 Hz), G(784 Hz), and C1(1064 Hz). The melodies consisted of seven piano tones (850 ms each) with total duration of approximately 6000 ms, and they were played at 70DB over headphones from .wav files with a 1000 ms break between melodies. In the testing phase,

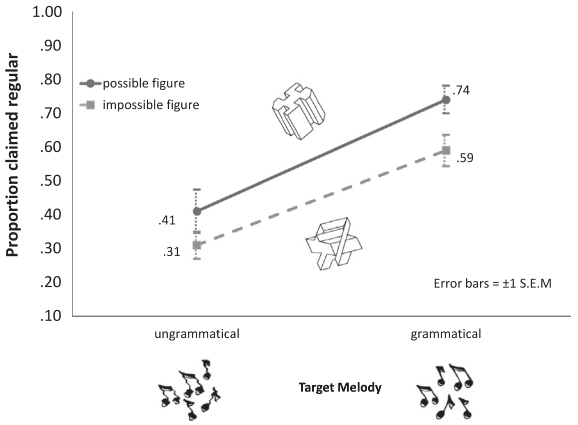

Fig. 1. Regularity judgments in Experiment 1.

which followed immediately after, participants heard 20 new melodies. 10 were grammatical, conforming to the original rules, and 10 were ungrammatical, violating the rules by one illegal tone transition. After each melody, participants were asked "does the melody conform to the rules of melodies from the previous phase of the experiment?" (YES/NO).[1]

During the testing phase, as a coherence manipulation, we presented, in random order, background pictures that were possible or impossible figures. These drawings could be instantiated in 3-D, or due to minimal changes, could not (Fig. 1; for details, Williams & Tarr, 1997). Each picture (250×250 pixels on a 1024×768 screen) was displayed throughout the melody (6000 ms). Participants were asked to watch the pictures as they would be asked questions about them afterwards. Finally, participants reported their general task impressions. Critically, no subject spontaneously reported using background figures as a cue to judge melodies. Participants either repeated the cover story (perception and memory), or said that the experiment was about learning musical rules.

3.2. Results

Fig. 1 shows regularity judgments for melodies. A 2 (Musical Grammaticality) $\times$ 2 (Visual Possibility) repeated-measures ANOVA revealed a Grammaticality main effect indicating that grammatical melodies were judged as more regular, $F(1,19) = 33.68$, $p < 0.01$, $\eta_p^2 = 0.64$. Importantly, there was also a main effect of Visual Possibility, such that participants made higher musical regularity judgments in the context of possible figures, $F(1,19) = 5.51$, $p < 0.03$, $\eta_p^2 = 0.23$. There was no interaction ($F < 1$), suggesting that auditory and visual sources of coherence feed into the same regularity judgment. There were no effects on regular RTs or logRTs (all $Fs < 1$).

[1] Grammatical melodies had no inherent "patternicity." Pretest ($N = 37$) without the initial rule-learning phase found no difference in regularity judgments between grammatical and ungrammatical melodies, $t(36) = 1.7$, $p > 0.1$.

4. Experiment 2

4.1. Method and participants

Experiment 1 found that cross-modal coherence influences regularity judgments. Experiment 2 explored this effect on memory judgments. The method was similar, but in the test phase we asked: "did this melody occur in the first part of the experiment?" (YES/NO). Note that all test melodies were actually new. But half were grammatical, thus globally similar to the originals. This enhances reliance on familiarity, even at short study-test delays (Shiffrin, Huber, & Marinelli, 1995) and opens memory judgments to non-specific influences.

Asking about memory has several advantages: First, it tests how cross-modal stimuli influence pattern-related beliefs without directly asking about regularity. Such influence should occur if coherence is indeed a non-specific experience that informs a variety of structural judgments (Whittlesea, 2002). Second, asking about memory for patterns from the study phase highlights to participants that the background stimuli (figures) from the test phase are irrelevant to the current task (since the study phase had no figures). This reduces the concern that participants are confused about which pattern they should rate, or use the backgrounds strategically. Finally, to assess the specificity of the coherence effect, after each memory judgment, participants indicated their liking for the pattern (1–9 scale). Sixteen undergraduates participated.[2]

4.2. Results

Fig. 2 shows "memory" judgments for melodies. Again, since all melodies were new, "old" judgments are technically false alarms. As shown, actual grammaticality of melodies increased claims of "recognition", $F(1,15) = 21.16$, $p < 0.01$, $\eta_p^2 = 0.59$. Critically, coherence of background figures did too, $F(1,15) = 4.8$, $p < 0.05$, $\eta_p^2 = 0.24$. Auditory regularity was additive with visual regularity (interaction $F < 1$). There were no effects on regular RTs or logRTs (all $Fs < 2$).

Liking ratings showed no grammaticality or possibility effects. Perhaps coherence experience is more about structure and thus more relevant for memory judgments (e.g., Whittlesea, 2002). Alternatively, because liking was rated second, coherence was (mis)attributed to the first, memory judgment (Schwarz & Clore, 2007).

Finally, when participants reported their task impressions, no subject spontaneously indicated using regularity of background figures to make memory judgments of melodies.

[2] A pretest ($N = 13$) revealed that our grammaticality procedure robustly influences "memory" judgments, independent of any visual manipulations. When the testing phase included no visual figures on the screen, "memory" of new but grammatical melodies was higher than of new but ungrammatical melodies (0.78 vs. 0.43), $t(12) = 4.74$, $p < 0.01$.

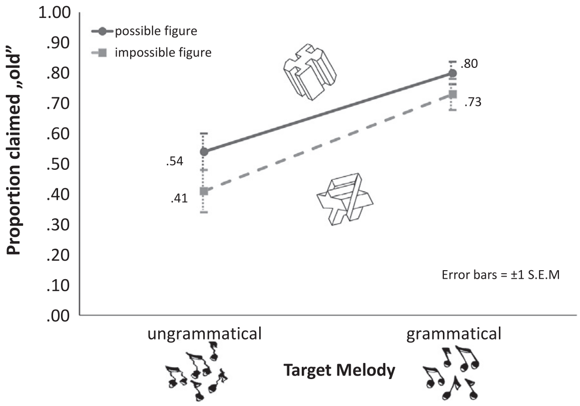

Fig. 2. Memory judgments in Experiment 2.

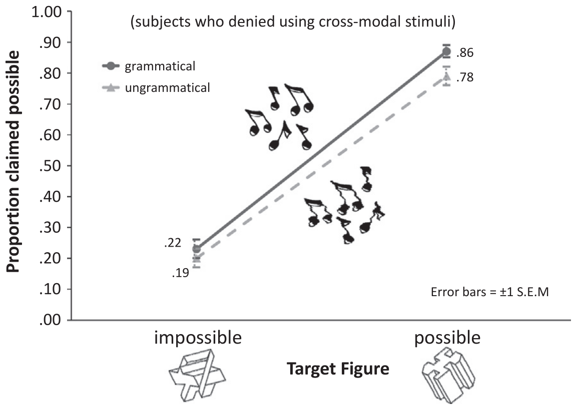

Fig. 3. Possibility judgments in Experiment 3.

5. Experiment 3

Experiment 3 again asked for decisions about pattern presence, while introducing several extensions. First, we reversed the modalities, such that figures served as targets and melodies as background. If coherence is indeed non-specific, background auditory coherence should influence regularity judgments of visual targets. Second, using background stimuli (melodies) that are made experimentally "regular" (via grammar learning) addresses concerns about background stimuli exploiting a preexisting regularity, which may be associated with other variables. Importantly, because our musical regularity manipulation is subtle (irregular sequences differ by one deviant note), we expected a weaker effect. Third, to address concerns about guessing, we systematically queried participants' task impressions and their judgmental strategies.

5.1. Participants and procedures

Seventy-six undergraduates participated for course credit. One participant did not read instructions and was dropped. The methods of the study phase matched Experiments 1 and 2, with participants first passively exposed to 20 grammar-conforming melodies. However, the testing phase was modified and the instructions now said: "*In this part, you are going to hear more melodies. Please listen to them, as we will ask you questions about the melodies later. At the end of each melody, a visual figure will be briefly presented on the screen. For each figure, your task is to decide whether the figure is possible or impossible. That is, please decide whether the figure depicts an object that could be constructed in a real, 3-D world. Please make your decision quickly, without sacrificing accuracy*."

Following these instructions, on each trial, participants first listened to a complete seven-tone melody (6000 ms duration, all melodies new, half grammatical). After the melody finished, a figure appeared briefly (750 ms) and was replaced immediately with "is this figure possible?" (YES/NO).

Finally, participants reported their task perceptions and strategies. First, participants typed their free response to "what do you think this experiment is testing?" Next, participants answered two filler questions about their impressions of the figures. Lastly, they answered the strategy question: "Did you use the melodies as a cue when judging whether the figures were possible?" (YES/NO). 16 participants (21%) responded YES. Consequently, we first present the results for participants who denied the use of cross-modal information, and then for all participants.

5.2. Results

Fig. 3 plots possibility judgments for participants who denied using melodies to judge figures. Unsurprisingly, possibility judgments were much higher for actually possible than impossible figures (0.82 vs. 0.20), $F(1,58) = 381.08$, $p < 0.01$, $\eta_p^2 = 0.87$. Critically, possibility judgments were about 5% higher in the context of coherent versus incoherent background melodies (0.54 vs. 0.49), $F(1,58) = 5.90$, $p < 0.05$, $\eta_p^2 = 0.09$. Again, the impact of Visual Possibility and melodic regularity was additive (interaction $F < 1.8$). In short, cross-modal coherence increased correct claims of pattern presence at the cost of claiming patterns where there were none. There were no effects on regular RTs or logRTs.

Interestingly, when the analyses include participants who answered YES to question about using melodies to judge figures, the grammaticality effect becomes borderline, $F(1,73) = 3.35$, $p = 0.07$, $\eta_p^2 = 0.04$. To understand why, we analyzed participants' freely reported impressions (available upon request) and found that YES participants judged figures using other aspects of melodies than regularity, such as melodic rise or fall (incidentally, those participants also responded faster $p < .05$). In short, explicit use of background stimuli appears to reduce, not increase reliance on cross-modal coherence (probably because regularity is not a salient dimension).

6. General discussion

In three experiments, incidental regular stimuli from another modality increased "pattern" claims, as assessed by diverse judgments – regularity, memory, and possibility. This effect occurred with different targets and modalities – melodies and figures. Regularity of targets and backgrounds combined across modalities in both directions, and worked additively, influencing both hit and false alarm rates. Our interpretation is that different coherence sources blend into the same global processing signal. However, we first consider alternative explanations.

Could incoherent backgrounds be distracting, reducing resources (e.g., attention) for detection of foreground coherence? Note that incoherent backgrounds did not lower discriminability, only introduced a bias against claiming the pattern. Could participants use the backgrounds strategically? But participants denied using cross-modal strategies, even when directly asked (Experiment 3). Could participants occasionally confuse targets with backgrounds? This account is unlikely, especially for Experiment 2 on "memory" for melodies, because background figures never appeared in the study phase, only at test. Finally, what about some other coherence-unrelated stimulus dimension? With figures, we exploited an objective regularity difference, but with melodies we manipulated subjective regularity on objectively similar material. Critically, the global nature of the influence, which occurred across different types of regularity, judgments, modalities, and directions, argues against explaining these effects via specific stimulus-bound features. All this suggests that the backgrounds influenced target judgments due to a common dimension of coherence. Simultaneously, our own explanation is that at its core the effect represents a cue integration phenomenon. We propose that sometimes regularity cues integrate in a nonspecific, unbound fashion. But, future research is needed to understand the specific integration level and whether a single processes or more processes with a common output are involved (e.g., Hillis, Ernst, Banks, & Landy, 2002). Finally, could our results be due not to "coherence" but different processing-related experience? Liking judgments (Experiment 2) showed no effect, which suggests some selectivity. Still, besides our method limitations, "liking" may not always capture affective or arousal connotations of global processing signals (Goldinger & Hansen, 2005; Winkielman, Huber, Kavanagh, & Schwarz, 2012).

Our results are compatible with any perspective that posits global, free-floating signals related to coherence, consistency, and related concepts (e.g., global prediction error, processing conflict). Some perspectives, including connectionist modeling, suggest that (in)coherent backgrounds make people actually hear or see patterns as more (ir)regular. However, our experiments were not designed to examine strong claims about low-level perceptual changes. Our data could equally reflect an influence on the higher-order, decision-related stages about regularity "claims". In fact, data patterns like ours (which in the language of SDT represent a bias) are compatible with both low-level (signal change) and high-level (decision change) interpretations (Wixted & Stretch, 2000).

Our favored decision-oriented theoretical perspective emphasizes subjective experiences (Kelley & Jacoby, 1998; Schwarz & Clore, 1997; Whittlesea, 2002). Since individuals have only one window into their experience, they can misread their sense of coherence (caused by the incidental, structurally unrelated stimulus) as bearing on the target. The current work suggests that such effects operate on fundamental cognitive judgments, such as regularity, previous occurrence, and possibility. Future research may explore such incidental influences on other experience-based judgments, including frequency, truth, or fame. However, for now, it appears that an ordered background makes people judge the world as more structured.

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