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Coherence across consciousness levels: Symmetric visual displays spare working memory resources

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ABSTRACT

Two studies demonstrate that the need for coherence could nudge individuals to use structural similarities between binary visual displays and two concurrent cognitive tasks to unduly solve the latter in similar fashion. In an overt truth-judgement task, participants decided whether symmetric colourful displays matched conjunction or disjunction descriptions (e.g., "the black and/or the orange"). In the simultaneous covert categorisation task, they decided whether a colour name (e.g., "black") described a two-colour object or half of a single-colour object. Two response patterns emerged as follows. Participants either acknowledged or rejected matches between disjunction descriptions and two visual stimuli and, similarly, either acknowledged or rejected matches between single colour names and two-colour objects or between single colour names and half of single-colour objects. These findings confirm the coherence hypothesis, highlight the role of coherence in preserving working-memory resources, and demonstrate an interaction between high-level and low-level consciousness.

1. Introduction

The sense of coherence (Antonovsky, 1987, 1993) is an enduring personality disposition and an important reservoir of coping resources (Larsson & Kallenberg, 1996; Lundberg & Nystrom, 1994; Pallant & Lae, 2002; Suominen, 1993; Surtees, Wainwright, Luben, Khaw, & Day, 2003). The need for coherence is also a basic dimension of human cognition. Indeed, the cognitive system yields coherent responses in complex cognitive tasks (Holyoak & Simon, 1999; Simon & Holyoak, 2002; Read, Snow, & Simon, 2003; Thagard, 1989) to make very different items fit well with each other (Thagard & Verbeurgt, 1998). For example, text comprehension requires individuals to assign meaningful structures to series of events in order to solve ambiguities, fill in gaps, and draw correct inferences (Graesser, Singer, & Trabasso, 1994; Kintsch, 1988). Similarly, single word recognition involves evaluating the coherence of distinct perceptual hypotheses such that comprehenders could determine which particular word a sequence of letters is most likely to form (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; McClelland & Rumelhart, 1981). Broadly speaking, two elements (e.g., concepts, propositions, image parts, goals, and actions) are coherent if they fit together and incoherent if they resist fitting together in a particular interpretation of events in the world (cf. Thagard & Verbeurgt, 1998).

Individuals also seek to establish coherence across tasks. For example, they could readily shift their beliefs on a set of arguments (i.e., concerning factual situations, public policy, business situations, or legal affairs) to make these arguments

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cohere both with one another and with a verdict they subsequently delivered as virtual judges (cf. Holyoak & Simon, 1999). Importantly, belief shifts occurred before reaching the verdict, suggesting that coherence is an objective people maintain throughout the decision-making process rather than a convenient instrument for consolidating a fait accompli.

We may thus view the need for coherence as a key attribute of conscious thought, which works towards constantly integrating upcoming (conflicting) information (e.g., Baars, 1988; Dehaene, Kerszberg, & Changeux, 1998). The opposite is not always true, as information integration could happen unconsciously (e.g., feature binding, multisensory binding). Nevertheless the distinction between conscious and unconscious processing is not clear-cut. Indeed, they follow similar principles of information processing hence knowledge that is initially encapsulated may become available to other parts of the cognitive system (Clark & Karmiloff-Smith, 1993; Cleeremans, 2008; Searle, 1992). This way, individuals may be able to use perceptual facts that are otherwise impenetrable to conscious processing for solving high-level cognitive tasks.

In the present paper, we aim to establish whether properties of low-level perceptual stimuli determine coherence across high-level cognitive tasks. There is ample evidence that perceptual stimuli interfere with and even hamper concurrent cognitive processes because of working memory limitations (e.g., De Neys & Schaeken, 2007; Klauer, Stegmaier, & Meiser, 1997; Knauff, Jola, & Strube, 2001), as discussed below. Therefore one might claim that reduced memory resources are responsible for random effects of perceptual information on higher-level cognitive tasks and therefore that such effects are mere accidents occurring once encapsulated perceptual processes are set in motion. Specifically, individuals may switch between automatic (i.e., low-level) and non-automatic (i.e., high-level) task performances without further integrating them by generating coherent responses. In contrast, if perceptual stimuli were to produce coherent effects (e.g., analogies or structural priming) involving the structure of two concurrent high-level tasks, we could infer that there is an interaction between low-level conscious processes and high-level consciousness, in one sense or the other. We investigated this claim in two experiments where we varied the degree of similarity between the structure of perceptual stimuli on the one hand, and the structure of cognitive tasks (i.e., categorisation and truth judgement) on the other hand. We predicted that high structural similarity would generate more coherence in responses to high-level tasks, whereas low structural similarity would generate less coherence. Working memory limitations might nevertheless resurface as a by-product of coherent responses across tasks in the form of incorrect solutions.

The remainder of this paper is organised as follows. After a brief overview of current evidence that working memory affects the interaction between visual stimuli and reasoning processes, we review the distinction between high-level and low-level conscious processes, as they illuminate the interaction between perception and cognition. Subsequently, we discuss a key means of achieving coherence, namely through analogy formation. Finally, we detail two experimental studies investigating whether the strength of structural coherence between perceptual stimuli and high-level cognitive tasks modulates response similarity.

1.1. Reasoning with visual displays: Working memory resources

Visual information is a significant vector for decision making in various cognitive domains including mathematical reasoning, syllogistic inference, and sentence structure assignment. Numerical calculations, for instance, involve attending to the way various elements are moved and transformed in reasoners' mind (Campbell, 1994; Landy & Goldstone, 2007; McNeil & Alibali, 2005; Zhang & Wang, 2005) and thus activate regions of the brain involved in spatial perception and working memory (e.g., Goel & Dolan, 2001; Knauff, Mulack, Kassubek, Salih, & Greenlee, 2002; Smith et al., 1995; Ungerleider & Mishkin, 1982). Indeed, information can readily transfer between cognitive domains such that, for instance, mathematical equations and sentence structures prime each other (cf. Scheepers & Sturt, 2014; also see Scheepers et al., 2011). Similarly, information can readily transfer between perceptual and cognitive domains such that, for instance, logical words (e.g., "and", "or") instantly affect visual stimuli processing (Dumitru, Joergensen, Cruickshank, & Altmann, 2013), which in turn affects their interpretation (Dumitru, 2014). Visual cues also modulate the decision to select a particular sentence structure, for example, the active-voice sentence *The shark ate the fish* over the passive-voice sentence *The fish was eaten by a shark*) (Gleitman, January, Nappa, & Trueswell, 2007; Tomlin, 1995 among others) sometimes by overriding language-specific preferences (Hwang & Kaiser, 2009; Myachykov, Garrod, & Scheepers, 2010; Myachykov & Tomlin, 2008).

An important consequence of shared working memory resources in cognition and perception is that visual information, in particular mental images containing visual details that are irrelevant to an inference, may impede reasoning and/or decision-making. Indeed, as reported in Knauff, Strube, Jola, Rauh, and Schlieder (2004), congenitally blind persons, most of whom do not construct visual mental images, perform better in reasoning tasks involving visual images compared to sighted persons. Moreover, as shown in Knauff and Johnson-Laird (2002), materials that are easy to envisage spatially can facilitate relational reasoning. Knauff et al. (2001), who used a secondary spatial task (visual or acoustical) alongside a main spatial reasoning task, provided further support for the hypothesis that reasoning relies on spatial memory resources. For example, participants' reporting whether a rectangle was moved leftwards or rightwards or whether a sequence of tones presented over headphones shifted to the left or to the right interfered with logical inferences. Such cross-modal interference effects support the mental models theory (Johnson-Laird, 1983) given that the process of building mental models for solving relational reasoning tasks recruits the central amodal visuospatial system and not a subordinate visual cognitive subsystem (i.e., the visuospatial sketchpad – cf. Baddeley's (1986) working memory model). Moreover, performance comparisons of experimental blocks versus the baseline condition suggest that results are unaffected by a shift in attention between the main task and the secondary tasks.