Consciousness and Cognition 53 (2017) 70–80

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

A role for visceral feedback and interoception in feelings-of-knowing

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ARTICLE INFO

Keywords:
Meta-memory
Interoception
Autonomic nervous system
Cardiovascular
Familiarity

ABSTRACT

Guided by the framework that autonomic feedback shapes emotional experience and other feeling states, we asked whether feeling-of-knowing (FOK) judgments may be influenced by visceral information through interoception. Participants performed a FOK task for previously studied face-name pairs while changes in cardiovascular and facial muscle activity were recorded. Previously studied face cues for which the corresponding name could not be recalled elicited an increased cardiac rate relative to novel face cues. Critically, the relationship between this pattern of cardiovascular activity and FOK ratings was moderated by interoception, such that for individuals with high interoceptive sensitivity, relative increases in cardiac rate for old items were associated with larger corresponding differences in FOK. Consistent with a link between familiarity and positive affect, we also found that old items elicited less frowning, as reflected in muscle activity recorded from the *corrugator* muscle. These results provide psychophysiological evidence that visceral signals contribute to experiential metamemory processes.

1. Introduction

The repertoire of mental experiences described as feelings is large and includes phenomena as diverse as hunger, fear, social rejection, or familiarity. A prominent perspective in psychology and the neurosciences holds that afferent visceral signals form a core element of subjective feelings (Damasio & Carvalho, 2013; James, 1894; Schachter & Singer, 1962). By this view, feelings are closely tied to the conscious representation of bodily states. Modern interest in feelings has been fuelled by methodological advances in the measurement of pertinent visceral signals, an increased understanding of mechanisms that allow for conscious perception of these signals, and the precise identification of neuroanatomical pathways that allow for the representation of visceral autonomic feedback in the human brain (see Craig, 2009; Critchley & Harrison, 2013; Wiens, 2005, for review). Most empirical and theoretical work on the visceral bases of feelings has focused on the issue in the context of emotion. However, feelings have also been implicated in various cognitive domains, including meta-cognition. Here, they are often referred to as "epistemic" feelings that pertain to unique phenomenological experiences associated with memory or knowledge (Arango-Munoz, 2014; Moulin & Souchay, 2013). Moreover, feelings are often referenced colloquially when people describe memory experiences such as familiarity, déjà vu, or knowing, in daily life. Yet, evidence directly relating such mnemonic experiences to visceral autonomic feedback remains sparse, in particular for conditions in which the stimulus or fact in question has no apparent emotional content (but see Fiacconi, Peter, Owais, & Köhler, 2016; Goldinger & Hansen, 2005; Morris, Cleary, & Still, 2008, for studies on familiarity).

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http://dx.doi.org/10.1016/j.concog.2017.06.001
Received 2 February 2017; Received in revised form 11 May 2017; Accepted 5 June 2017
Available online 20 June 2017

Over the past decade, researchers interested in understanding the functional contributions of visceral signals have started to turn their attention to the question of how inter-individual differences in bodily awareness shape the influence of such signals on experience and behaviour (Dunn et al., 2010; Garfinkel et al., 2013; Pollatos, Herbert, Matthias, & Schandry, 2007). Defined as the ability to perceive internal bodily signals, *interoception* is often assessed with tasks that require participants to actively monitor their heartbeats. One of the most widely used experimental paradigms to probe interoception is the heartbeat-counting task developed by Schandry (1981), in which participants count the number of heartbeats they perceive over a series of set time intervals. Participants' interoceptive sensitivity is then computed by comparing the reported and objective number of heartbeats, with the latter typically derived from recordings of cardiovascular activity via electrocardiography (ECG). Interoceptive sensitivity as assessed by the heartbeat counting task has been shown to be positively related to performance in various domains including, but not limited to emotion (e.g., Ainley, Brass, & Taskiris, 2014; Barrett, Quigley, Bliss-Moreau, & Aronson, 2004; Meissner & Wittmann, 2011; Pollatos et al., 2007; Werner, Peres, Duschek, & Schandry, 2010). The surging interest in interoception stems in large part from its utility in interpreting observed associations between task-related changes in visceral signals and behaviour. If, as suggested by James' theory of emotion and its modern variants (Damasio & Carvalho, 2013; James, 1894; Schachter & Singer, 1962), the perception of afferent autonomic signals forms the basis of feeling states and related behaviours, then one might predict that individuals who are more adept at perceiving this information ought to demonstrate a tighter coupling between task-relevant fluctuations in autonomic activity and behaviour. In support of this idea, Dunn et al. (2010) found, for example, that during emotional picture viewing, only individuals with high interoceptive sensitivity showed a positive relationship between picture-related changes in heart rate (HR) and arousal ratings. Critically, however, this moderating role of interoceptive sensitivity was not limited to tasks that require the explicit use of emotional information, but was also observed in a putatively more cognitive paradigm. In a second experiment, Dunn et al. (2010) found that autonomic reactivity was positively correlated with successful performance in an intuitive decision-making task only in those individuals with high interoceptive sensitivity. Together, these findings highlight how examination of inter-individual differences in interoception can shed light on the functional role of visceral signals in guiding behaviour, and demonstrate that such signals also shape behaviour in tasks that do not contain stimuli with explicit emotional content.

In the present study, we followed a similar rationale and leveraged inter-individual differences in interoception in order to examine a potential role for autonomic signals in shaping epistemic feelings. In particular, we focused on a feeling state associated with a well-studied meta-memory phenomenon known as *feeling-of-knowing* (FOK; Hart, 1967). This phenomenon refers to experiences in which a person has a strong sense that information about a stimulus or a fact (e.g., 'what is the name of the person shown in this photograph'; 'what is the capital of Albania') is available, despite unsuccessful attempts to recall it in the present situation. In the laboratory, FOKs are typically probed with judgements that require participants to estimate the prospective likelihood that currently unrecallable information would be accurately identified when presented in a recognition-memory test. There is a growing body of evidence to suggest that FOK judgments are inferential in nature, and build on the use of heuristics that involve implicit evaluation of the familiarity of the stimulus cue or the ease with which relevant information can be brought to mind (Reder & Ritter, 1992; Schwartz & Metcalfe, 1992; Metcalfe, Schwartz, & Joaquim, 1993; Koriat and Levy-Sadot, 2001; Koriat, 1993). Such heuristics have been classified as experience-based and have been contrasted with information-based sources of FOK judgements that involve analytical reasoning and the application of domain-specific knowledge (Koriat, 2000, 2006). In the current study, we hypothesized that experience-based FOKs are shaped by the type of autonomic feedback that is thought to underlie feelings more broadly (Damasio & Carvalho, 2013).

Although, to our knowledge, there is currently no evidence that directly speaks to whether autonomic feedback shapes FOK, findings from recent experimental work on other aspects of meta-cognition hint that such an influence may indeed exist. For example, Garfinkel et al. (2013), focusing on mechanisms involved in memory formation, reported that interoceptive sensitivity modulates the extent to which confidence judgments for detecting briefly presented targets predicts subsequent memory performance for those targets. This finding points to a link between interoception and processes involved in the internal evaluation of accuracy of cognitive processing. Recent work by Chua and Bliss-Moreau (2016) provides additional support for this link in the context of meta-memory experiences. Specifically, these authors found that individuals with greater overall bodily awareness, as indexed by the Body Awareness Questionnaire (Shields, Mallory, & Simon, 1989), were more confident in their responses to general knowledge questions. Moreover, they reported that higher interoceptive sensitivity, as reflected in scores for the heartbeat-counting task, is associated with a tighter coupling between confidence and accuracy in recognizing previously studied face-name pairs. While these results are consistent with a role for visceral information in shaping meta-memory judgments and experiences, there has yet to be a systematic examination of how changes in autonomic activity observed during the execution of meta-memory tasks are related to the experiential elements associated with performance. The present study was conducted to examine this relationship, as well as its potential dependence on individual differences in interoception. To the extent that the functional influence of visceral signals on epistemic feelings depends on interoception, this approach holds the potential to reveal a key role for visceral signals in such feelings, including FOK.

With this goal in mind, the experimental approach used in the current study was similar to that employed by Dunn et al. (2010). Specifically, we measured trial-specific fluctuations in cardiovascular activity (i.e., in the inter-beat interval; IBI) as a marker of autonomic feedback while participants made FOK judgments in a task that required recovering the names associated with previously studied faces, i.e. a meta-memory task that probed episodic FOKs (Souchay, Guillery-Girard, Pauly-Takacs, Wojcik, & Eustache, 2013). For purpose of comparison, we also included novel face cues. The aforementioned heartbeat counting task (Schandry, 1981) was administered in order to measure interoceptive sensitivity. We expected that, if FOK experiences are indeed shaped by afferent visceral feedback, inter-individual differences in interoceptive sensitivity would moderate the relationship between changes in cardiac rate during the retrieval phase of the FOK task and the magnitude expressed in corresponding FOK judgments. In particular,