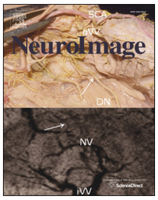
NeuroImage xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

NeuroImage

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



You'd Better Think Twice: Post-Decision Perceptual Confidence

Raphael Hilgenstock [a,b,*], Thomas Weiss [c], Otto W. Witte [a,d]

[a] *Hans Berger Department of Neurology, Jena University Hospital, Friedrich Schiller University, 07743 Jena, Germany*
[b] *Department of Pediatrics, HELIOS Children's Hospital Wuppertal, Witten/Herdecke University, 42283 Wuppertal, Germany*
[c] *Department of Biological and Clinical Psychology, Friedrich Schiller University, 07743 Jena, Germany*
[d] *Center for Sepsis Control and Care, Jena University Hospital, Friedrich Schiller University, 07743 Jena, Germany*

ARTICLE INFO

Article history:
Accepted 15 May 2014
Available online xxxx

Keywords:
perceptual decision making
post-decision confidence
metacognition
fMRI
grating orientation task
anterior prefrontal cortex

ABSTRACT

Current findings suggest that confidence emerges only *after* decision making. However, the temporal and neural dynamics of the emergence of post-decision confidence – a metacognitive judgement – are not fully explored. To gain insight into the dynamics of post-decision confidence processing and to disentangle the processes underlying confidence judgements and decision making, we applied a tactile discrimination task during functional magnetic resonance imaging (fMRI). Our results revealed that reaction times to post-decision confidence depend on the level of confidence, suggesting that post-decision confidence in a perceptual choice is not processed in parallel to perceptual decision making. Moreover, we demonstrated by the parametric analysis of fMRI data that post-decisionally modelled confidence processing can be distinguished from processes related to decision making through anatomical location and through the pattern of neural activity. In contrast to perceptual decision making, post-decision confidence appears to be strictly allocated to a prefrontal network of brain regions, primarily the anterior and dorsolateral prefrontal cortex, areas that have been related to metacognition. Moreover, the processes underlying decision making and post-decision confidence may share recruitment of the dorsolateral prefrontal cortex, although the former probably has distinct functions with regard to processing of perceptual choices and post-decision confidence. Thus, this is the first fMRI study to disentangle the processes underlying post-decision confidence and decision making on behavioural, neuroanatomical, and neurofunctional levels. With regard to the temporal evolution of post-decision confidence, results of the present study provide strong support for the most recent theoretical models of human perceptual decision making, and thus provide implications for investigating confidence in perceptual paradigms.

© 2014 Published by Elsevier Inc.

UNCORRECTED PROOF

Introduction

Much theoretical work has been carried out in the effort to understand human decision making. Choice, decision time, and confidence have emerged from these efforts as key concepts of understanding and of modelling the processes underlying decision making (Kepecs and Mainen, 2012; Pleskac and Busemeyer, 2010). Yet the temporal and neural dynamics of the processes underlying the emergence of confidence and a metacognitive judgement about confidence are not fully characterized. Recent findings indicate that the formation of confidence emerges only after primary (e.g., perceptual) decision making. For example, while reaction times (RTs) related to perceptual decisions (PRTs) vary linearly with regard to confidence ratings, subsequent reaction times on the level of confidence (CRT) in the preceding perceptual decision vary non-linearly as a function of confidence ratings, which has been interpreted to indicate an ongoing accumulation of evidence (Petrusic and Baranski, 2003). Resulaj et al. (2009) investigated changes of mind after primary decision making in a motor paradigm; this study also indicated ongoing information processing that could be related to the emergence of confidence (Van Zandt and Maldonado-Molina, 2004). Based on these and similar findings, the two-stage dynamic signal detection (2DSD) model, a comprehensive model of human decision making, has been conceptualised (Pleskac and Busemeyer, 2010). The model postulates that perceptual choice (e.g., categorizing noisy images into distinct classes or assessing the orientation of a tactile grating) and confidence differ in terms of the amount of accumulated evidence. Accordingly, confidence and a metacognitive judgement about confidence only come into existence post-decisionally by the ongoing accumulation of information. This assumption, as implemented in the 2DSD model, offers the advantage of accounting for all three key aspects of human decision making, including confidence judgements or, within the framework of the model, post-decision confidence.

Abbreviations: APFC, anterior prefrontal cortex; BOLD, blood oxygen level dependent; CRT, confidence reaction time; DLPFC, dorsolateral prefrontal cortex; FCT, functional connectivity toolbox; fMRI, functional magnetic resonance imaging; GOT, gratings orientation task; HRT, hemodynamic response function; MNI, Montreal Neurological Institute; PSC, percent signal change; PRT, perceptual reaction time; ROI, region of interest; rWLS, robust weighted least-square regression; SMG, superior medial gyrus; SPM, statistical parametric map; 2DSD, two-stage dynamic signal detection.

* Corresponding author at: Department of Pediatrics, HELIOS Children's Hospital Wuppertal, Witten/Herdecke University, 42283 Wuppertal, Germany.
E-mail address: Raphael.Hilgenstock@helios-kliniken.de (R. Hilgenstock).

http://dx.doi.org/10.1016/j.neuroimage.2014.05.049
1053-8119/© 2014 Published by Elsevier Inc.

UNCORRECTED PROOF

The difference between post-decision confidence and perceptual choice may not only be quantitative – with regard to the amount of accumulated sensory evidence over time – but may also be qualitative. Kiani and Shadlen (2009) suggest that perceptual choices may simply result from the raw data provided by secondary cortices, especially the parietal cortex, involved in the accumulation of sensory evidence. Thus, at the time of perceptual choice only a preliminary conceptualisation of confidence may emerge that is not available for a metacognitive report (Fleming et al., 2012; Kepecs and Mainen, 2012; Middlebrooks and Sommer, 2012). However, these raw data may subsequently translate into higher order cognitive processing in prefrontal areas where metacognitive judgements about confidence emerge (Bode et al., 2012; Kepecs and Mainen, 2012; Kiani and Shadlen, 2009). Accordingly Fleming et al. (2010, 2012) and Yokoyama et al. (2010), for example, provide evidence to indicate that metacognitive ability, the accuracy of confidence, is located primarily in the anterior prefrontal cortex (APFC). Thus, perceptual decision making and the formation of post-decision confidence likely differ not only with regard to their temporal dynamics, but also differ qualitatively through their recruitment of higher order cognitive processes in a distinct network of brain areas. These differences may be linked to behavioral discrepancies between perceptual choice and post-decision confidence, as is indicated by the phenomena of over- and underconfidence. Overconfidence and underconfidence refer to discrepancies between objective task performance at the time of decision making and expected performance based on post-decision confidence ratings (Baranski and Petrusic, 1995; Juslin, Winman, and Olsson, 2000; Pleskac and Busemeyer, 2010).

Despite these findings indicating that perceptual choice and post-decision confidence may differ on temporal, behavioral, and neural scales, to the best of the authors' knowledge no study has rigorously attempted, using fMRI, to delineate the processes underlying perceptual decision making, confidence associated with the decision making process, and the emergence of post-decision confidence. Therefore, the present study was primarily intended (1) to provide insight into the temporal dynamics of post-decision confidence, (2) to achieve a better understanding of the underlying functional somatosensory network of post-decision confidence, and thus (3) to investigate differences between perceptual choice and confidence embedded in the assumption of a post-decisional emergence of confidence.

Method

Subjects

Altogether, 26 subjects were recruited to participate in the study. Two subjects were excluded—one because of excessive motion during scanning, and the other because of technical problems with the device used for psychophysical testing during the scanning procedure. Consequently, the study had 24 participants (18 females; ages 18–27 years), all healthy, with no history of neurological or psychiatric disorders, trauma, or brain abnormalities. All subjects were right-handed, as assessed by the high-validity subset of the Edinburgh handedness inventory (Raczkowski et al., 1974). All subjects gave informed written consent after explanation of the experimental procedure. The study was approved by the local ethics committee.

Psychophysical testing

The Grating Orientation Task (GOT; van Boven and Johnson, 1994), which requires subjects to indicate the orientation of tactile gratings, was used to assess tactile acuity (Fig. 1). We modified the original GOT task. Our subjects were required to indicate the orientation of a stimulus pair according to four response alternatives (lengthwise–lengthwise, lengthwise–crosswise, crosswise–lengthwise and crosswise–crosswise; see Fig. 2). Additionally, subjects were requested to indicate their level of confidence in their preceding perceptual decision, using indicators analogous to Petrusic and Baranski (2003): "guess", "slightly certain", "moderately certain", and "certain".

For the subsequent fMRI testing, we selected two stimuli, individual to each subject, one grating for which the orientation was easily identified ("easy pen," $P(\text{correct}) = 75–100\%$), and a second grating for which the orientation was more difficult to identify ("difficult pen", $P(\text{correct})$ 30–60%). Gratings were chosen to individually maximize the distribution of confidence ratings over the four levels of choice confidence.

MRI: Pretesting

Two fMRI practice sessions were carried out to refine the choice of gratings for the main fMRI experiment and to acquaint subjects with the fMRI setting and design. Each trial was announced by three transverse white bars that were presented for 0.5 s. Subsequently, GOT-pens were presented twice, for two seconds each time, and with a two-second pause between pens. Subjects rated the orientation of a stimulus pair according to four response alternatives: lengthwise–lengthwise, lengthwise–crosswise, crosswise–lengthwise and crosswise–crosswise. Immediately afterwards subjects indicated their level of confidence associated with this preceding decision on stimulus-pair orientation (guess, slightly certain, moderately certain, and certain) within four seconds. A fixation cross was shown between trials (see Fig. 2). Altogether, 30 trials were presented in each practice session.

A pneumatically driven, MRI-compatible stimulator was used for stimulus presentation. The sequence and duration of stimulus presentation were controlled using the software Presentation (Neurobehavioral Systems, Albany, CA).

MRI: Main experiment

The main experiment consisted of 108 tactile task trials (Fig. 2). In total, participants were presented with 48 pairs of easy tactile gratings and 60 pairs of difficult tactile gratings. The study design used a larger number of difficult trials in response to the phenomenon

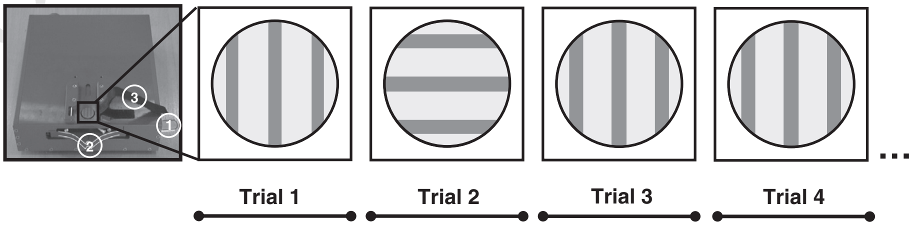


Fig. 1. The device used for psychophysiological testing and an exemplary sequence of gratings. Eight gratings, each with a surface of different ridge and groove widths (0.25; 0.5; 0.7; 1.0; 1.2; 1.5; 2.0; 3.0), were mounted on a rotatable disk inside the custom-made device depicted at the far left part of Fig. 1. GOT-gratings were presented by releasing a lever on side of the device (1) and changed by another control shifter on its front (2, indicated by white lines). The index finger was immobilized by hook-and-loop tape (3) to eliminate the potential for introduction of confounds. As an example, a GOT-grating with a large resolution is shown (dark grey corresponds to grooves, light gray to ridges). Testing was conducted in a stepwise block procedure, beginning with the pen having the largest "resolution" of 3 mm. Within each block, 20 stimulus *pairs* were presented. Each of the four possible combinations of pairs was presented five times within each block, in pseudo-randomized sequences that changed every block. The stepwise testing procedure was carried out twice.

Please cite this article as: Hilgenstock, R., et al., You'd Better Think Twice: Post-Decision Perceptual Confidence, NeuroImage (2014), http://dx.doi.org/10.1016/j.neuroimage.2014.05.049

Download English Version:

https://daneshyari.com/en/article/6027104

Download Persian Version:

https://daneshyari.com/article/6027104

Daneshyari.com