NeuroImage 113 (2015) 164–174

Contents lists available at ScienceDirect

NeuroImage

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

Memory detection using fMRI — Does the encoding context matter?

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ARTICLE INFO

Article history:
Accepted 18 March 2015
Available online 25 March 2015

Keywords:
Concealed Information Test
Functional MRI
Electrodermal responses
Encoding context
Memory
Mock crime
Multivariate pattern analysis

ABSTRACT

Recent research revealed that the presentation of crime related details during the Concealed Information Test (CIT) reliably activates a network of bilateral inferior frontal, right medial frontal and right temporal–parietal brain regions. However, the ecological validity of these findings as well as the influence of the encoding context are still unclear. To tackle these questions, three different groups of subjects participated in the current study. Two groups of guilty subjects encoded critical details either only by planning (guilty intention group) or by really enacting (guilty action group) a complex, realistic mock crime. In addition, a group of informed innocent subjects encoded half of the relevant details in a neutral context. Univariate analyses showed robust activation differences between known relevant compared to neutral details in the previously identified ventral frontal–parietal network with no differences between experimental groups. Moreover, validity estimates for average changes in neural activity were similar between groups when focusing on the known details and did not differ substantially from the validity of electrodermal recordings. Additional multivariate analyses provided evidence for differential patterns of activity in the ventral fronto-parietal network between the guilty action and the informed innocent group and yielded higher validity coefficients for the detection of crime related knowledge when relying on whole brain data. Together, these findings demonstrate that an fMRI-based CIT enables the accurate detection of concealed crime related memories, largely independent of encoding context. On the one hand, this indicates that even persons who planned a (mock) crime could be validly identified as having specific crime related knowledge. On the other hand, innocents with such knowledge have a high risk of failing the test, at least when considering univariate changes of neural activation.

Introduction

The usage of brain imaging techniques to identify lies has been frequently investigated over the last decade (e.g., Kozel et al., 2005, 2009; Langleben et al., 2002) and critically discussed in the scientific community (e.g., Greely and Illes, 2007). Although initial studies aimed at detecting a specific signature of deceit in the brain activity, it has been recently emphasized that deception rather seems to unspecifically recruit a number of brain regions related to more general processes, especially memory (Farah et al., 2014).

A technique that specifically focuses on the detection of crime related memories is the Concealed Information Test (CIT; Lykken, 1959, 1974). This test consists of multiple-choice questions that ask for details of a crime under investigation. For each question, the correct answer (e.g., the jewelry that was stolen) is presented together with different neutral answer alternatives (e.g., other potentially stolen goods). The general idea of the CIT is that only a guilty person will recognize the correct detail among these alternatives and show stronger physiological responses to this item. An innocent without such knowledge should respond unsystematically across answer options. Previous studies confirmed that guilty subjects show larger skin conductance responses as well as heart rate deceleration and respiratory suppression to crime related details (e.g., Gamer et al., 2006). Laboratory studies reported high validity coefficients for the differentiation between guilty and innocent persons on the basis of such autonomic measures (for reviews see Ben-Shakhar and Elaad, 2003; Meijer et al., 2014).

Only few neuroimaging studies investigated neural responses in a CIT design so far. They consistently reported higher activity for critical compared to neutral answer alternatives in a ventral fronto-parietal network consisting of the bilateral inferior frontal gyrus (IFG), the right middle frontal gyrus (rMFG) and the right temporoparietal junction (rTPJ) (Gamer, 2011). These regions are not exclusively involved in the concealment of knowledge but rather reflect attentional orienting (Downar et al., 2000, 2002; Kiehl et al., 2001), response monitoring and inhibition (Aron et al., 2004; Wager et al., 2005) as well as memory processes (D'Esposito et al., 2000; Iidaka et al., 2006).

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http://dx.doi.org/10.1016/j.neuroimage.2015.03.051
1053-8119/

Importantly, the existing neuroimaging CIT experiments were based on memory for highly salient autobiographical information (Ganis et al., 2011), artificial stimuli like playing cards (e.g., Gamer et al., 2007; Langleben et al., 2002; Nose et al., 2009) or imagined crime scenarios (Cui et al., 2014). Thus, there is a lack of research investigating the neural correlates of the CIT under realistic conditions, for example following the planning and execution of a mock crime. This approach better resembles field conditions (Osugi, 2011) and represents the optimal setting for a CIT examination in the laboratory (Ben-Shakhar and Elaad, 2003). Moreover, recent studies on autonomic responses in the CIT further improved this approach by enabling only incidental encoding of the crime related information to better resemble field conditions (e.g., Gamer et al., 2010; Peth et al., 2012).

Moreover, the specific encoding context might modulate the detection of concealed information. For example, previous CIT studies reported successful detection of concealed knowledge related to criminal intentions based on skin conductance responses (Meijer et al., 2010), event-related brain potentials (Meixner and Rosenfeld, 2011) and behavioral measures (Noordraven and Verschuere, 2013), but it remains unclear whether comparable effects can also be observed in fMRI data. Furthermore, it is currently unknown whether criminal intention and action result in different physiological responses in the CIT. A second line of research contrasted participants who were guilty of committing a mock crime with a sample of innocents who were informed about crime related details. Some of these studies reported differences in autonomic responding to crime details between these groups (Ben-Shakhar et al., 1999; Bradley et al., 1996; Bradley and Rettinger, 1992; Bradley and Warfield, 1984; Giesen and Rollison, 1980; Stern et al., 1981) whereas other studies failed to find a significant differentiation (Gamer, 2010; Gamer et al., 2010). So far, no fMRI study systematically examined the influence of encoding context on recognition of relevant crime details in the CIT.

To close this gap, the current study aimed at investigating three groups of subjects that differed regarding the context of information encoding (guilty action group, guilty intention group, innocent group) with an fMRI-based CIT. Electrodermal responses were additionally recorded to enable a comparison to traditional polygraph measures. While the guilty action group knew all relevant details, the guilty intention and the innocent group were unaware of half of the relevant details, respectively. The guilty intention group could only know details from the planning phase, while the innocent group could gain knowledge of half of the details from the planning and the action phase, respectively, by executing a neutral task. Such design enabled the examination of group differences in responding to known critical details as well as the calculation of validity estimates for the "traditional" comparison of informed (guilty) and uninformed (innocent) subjects (cf., Ben-Shakhar and Elaad, 2003). Based on the above-mentioned literature, we hypothesized increased activation in the previously reported ventral fronto-parietal network (Gamer, 2011) when contrasting known relevant details with neutral alternatives across all groups.

In addition to this network, several regions of interest were defined to further explore whether differences in encoding context affect neural activation. As previous research on memory reported enhanced activation in the supramarginal gyrus (SMG) for information encoded during actions compared to imagined actions (Russ et al., 2003), we expected comparable differences between the guilty action and the guilty intention group. Due to their involvement in the retrieval of emotional memories (for review see Dolcos et al., 2012), we furthermore expected differences in amygdala and hippocampus activation between the guilty action and the innocent group. Moreover, we conducted multivariate analyses (Bles and Haynes, 2008) to examine whether the multivariate pattern of brain activity allows for differentiating experimental groups.

Finally, the current data enable a direct comparison between the classification accuracy of neural and electrodermal response measures that were recorded simultaneously. Therefore, this study adds significantly to the current discussion about whether neuroimaging methods are superior to traditional polygraphy in the detection of concealed information (Gamer, 2014).

Materials and methods

Participants

This study was approved by the local ethics committee and conducted according to the principles expressed in the Declaration of Helsinki. All participants gave written informed consent and were paid 50 Euro for participation. The final sample consisted of 60 right-handed participants with 20 participants in the guilty action group (6 women, mean age of 26.2 years), 20 participants in the guilty intention group (6 women, mean age of 23.9 years) and 20 participants in the innocent group (6 women, mean age of 25.7 years). No difference in age was found between the three groups, $F(1,58) < 1$. Most participants were students from various faculties (70%). During data collection, eight persons had to be excluded from the study because of different reasons and were replaced by new subjects. Reasons for exclusion were technical difficulties ($n = 3$), an incomplete fulfillment of the mock crime ($n = 3$) or alcohol intoxication ($n = 2$).

Design

A realistic mock crime procedure was either only planned (guilty intention group) or really enacted (guilty action group) by subjects in the guilty groups. Persons who belonged to the guilty intention group knew only relevant details that belonged to the planning phase, whereas the guilty action group knew all relevant details. In addition, a third group of persons fulfilled a non-criminal task before they were examined with the same CIT (innocent group). These subjects knew half of the relevant details from a neutral context, and found out during the CIT that these details were also part of a mock crime. Each group consisted of 20 subjects and participants were randomly assigned to their respective experimental condition by means of a predefined list.

Procedure

The experiment was conducted in three different stages. Stage 1 was a planning phase that lasted for one week (study days 1–7). During this time period, participants received several emails from a fictitious confederate that asked them to either prepare a mock crime (guilty subjects) or an errand (innocents). The mock crime involved the theft of money and a CD with important study information and participants were informed about the precise place and timing of the theft during the planning phase. The innocent participants prepared to meet a person to get a CD for somebody else and received similar information on the details of this errand. To ensure active preparation of "criminal" and "neutral" activities, respectively, participants had to answer emails from the confederate and find out certain details about the upcoming event by themselves (e.g. by looking up specific details on the website of the University Medical Center Hamburg-Eppendorf where the event was about to take place). Stage 2 was the enactment phase and took place after the preparation week on study day seven. Here, the guilty action group committed the previously prepared mock crime, and the innocent participants fulfilled the errand. Participants of the guilty intention group, however, were stopped before they could enact the mock crime and were immediately investigated with the CIT (for a detailed description of stage 1 and stage 2, see *Supplementary Methods*).

Stage 3 consisted of the CIT examination. Participants of the guilty intention group accomplished the CIT on day seven. Participants of the guilty action group and all innocent participants arrived on day eight for the CIT investigation, one day after completion of their respective task. The CIT was conducted by an examiner unknown to