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Effects of Temporal Unpredictability in the Stimulus Sequence in Cognitive and Emotional Tasks

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Over the past twenty years, functional magnetic resonance imaging (fMRI) research has focused on identifying neuronal substrates of brain function in animals and humans and has delivered valuable results for cognitive neuroscience. By employing sophisticated experimental designs, researchers are able to induce quite specific cognitive processes of interest while simultaneously measuring brain responses dedicated to their mediation. Fundamental to this kind of research is that the observed effects are attributable to the actually desired cognitive processes and not to other interfering sources, that is, potential confounds. To ensure that the psychological processes under investigation are not influenced by confounds in the experimental design, the latter is typically conceptualized to control for known confounding variables such as e.g. stimulus sequence or task order effects. However, comparatively little attention has been directed to the effects of a specific potential confound, the temporal structure of the stimulus sequence. The present thesis is therefore concerned with the question of how small changes in stimulus timing affect behavioral and brain performance and whether they need to be taken into account when designing an experiment.

In fMRI research, stimulus timing is associated to the optimization of design efficiency: in contrast to blocked designs, event-related designs require jittering and therefore the application of variable, as compared to constant, interstimulus intervals (ISIs). However, variable ISIs are also less predictable and predictability is a strong determinant of behavioural and brain performance. For example, studies employing temporal cues – guiding attention towards temporal information – have demonstrated that predictable and unpredictable stimulus events show large differences in processing. Albeit not many experimental designs employ temporal cues, most designs in cognitive neuroscience do present stimuli and hence some implicit form of temporal structure. In essence, stimuli may be presented at either predictable (constant) or unpredictable (variable) ISIs. In two conducted studies, the present thesis examines effects of the application of variable and constant ISIs on behaviour and brain activation during a variety of different cognitive tasks.

The first study investigates how implicit temporal unpredictability, in the form of stimuli presented at constant and variable ISIs, affects the processing of cognitive tasks with different demands on working memory and response selection processes. The second study is concerned with the question of how variations in temporal unpredictability affects the processing of stimuli with emotional and non-emotional content.

Both studies prove that small variations in the temporal structure of the stimulus sequence affect cognitive processing and behavioural performance, and that the magnitude of this effect moreover depends on cognitive task demands. Non-emotional neutral stimuli presented at variable ISIs result in reduced performance and enhance brain activation particularly in the amygdala, as well as in fronto-parietal areas depending on the specific demands required by the cognitive task. These areas also encode temporal expectations, i.e. their activation co-varies with the cumulative probability that a stimulus will occur given it has not already occurred. In contrast, the application of emotional stimulus material seems to impede the encoding of conditional expectations. Therefore, slight variations in the temporal stimulus structure, differentially affects stimuli of emotional vs. non-emotional valence, reflected in deviating activation patterns.

As a consequence of these results, stimulus timing may represent a strong potentially confounding source to neuroimaging studies which aim at elucidating the contribution of certain brain areas to (social) cognition. Since effects of unpredictable timing vary depending on task demands such as working memory and emotion processing, the implicit temporal stimulus structure needs to be taken into account when designing an experiment.