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Review

Time perception in depression: A meta-analysis

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ABSTRACT

Background: Depressive patients frequently report to perceive time as going by very slowly. Potential effects of depression on duration judgments have been investigated mostly by means of four different time perception tasks: *verbal time estimation*, *time production*, *time reproduction*, and *duration discrimination*. Ratings of the subjective *flow of time* have also been obtained.

Methods: By means of a classical random-effects meta-regression model and a robust variance estimation model, this meta-analysis aims at evaluating the inconsistent results from 16 previous studies on time perception in depression, representing data of 433 depressive patients and 485 healthy control subjects.

Results: Depressive patients perceive time as going by less quickly relative to control subjects ($g=0.66$, $p=0.033$). However, the analyses showed no significant effects of depression in the four time perception tasks. There was a trend towards inferior time discrimination performance in depression ($g=0.38$, $p=0.079$). The meta-regression also showed no significant effects of interval duration. Thus, the lack of effects of depression on timing does not depend on interval duration. However, for time production, there was a tendency towards overproduction of short and underproduction of long durations in depressive patients compared to healthy controls.

Limitations: Several aspects, such as influences of medication and the dopaminergic neurotransmitter system on time perception in depression, have not been investigated in sufficient detail yet and were therefore not addressed by this meta-analysis.

Conclusions: Depression has medium effects on the subjective flow of time whereas duration judgments basically remain unaffected.

Contents

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1. Introduction

Depressive patients frequently report to perceive time as passing by extremely slowly (Blewett, 1992; Ratcliffe, 2012; Straus, 1947). However, the question of whether time perception in the sense of judgments of defined time intervals is also affected by depression remains unresolved. We are faced with a large body of inconclusive and often contradictory findings. The present meta-analysis evaluates the existing literature on time perception in depression.

Over the last few decades, the potential effects of depression on time perception have been investigated empirically mostly by means of four different experimental tasks (see Msetfi et al., 2012 for a recent review). These tasks are (a) *verbal time estimation* (sometimes referred to as *'time estimation'*), where a time interval is presented, defined for instance by the inter-onset interval between two brief tones, and the subject gives an estimate in conventional time units like seconds (e.g., Bech, 1975; Bschor et al., 2004; Dilling and Rabin, 1967; Kitamura and Kumar, 1983), (b) *time production,* where the experimenter specifies a time interval in temporal units, and the subject produces this interval for example by pressing a button to mark the interval's beginning and end (e.g., Münzel et al., 1988; Tysk, 1984), (c) *time reproduction,* where a time interval is presented as in (a) and the subject produces a corresponding interval as in (b) (Mahlberg et al., 2008; Mundt et al., 1998), and (d) *duration discrimination*, where typically two time intervals of almost equal length are presented successively, and the subject selects the longer interval (Msetfi et al., 2012; Rammsayer, 1990; Sevigny et al., 2003). For tasks (a) to (c), most studies focused on the mean duration of the time estimates, or on deviations of the estimates from the veridical values. Thus, in terms of Fechner (1860), the studies compared the "constant error" between depressive patients and controls. For duration discrimination (task (d)), performance is often characterized in terms of the duration difference limen, defined as for example the difference in duration between the two presented time intervals that results in 75% correct responses. It should be noted that for tasks (a) to (c) a corresponding measure of sensitivity is provided by the standard deviation of the estimates or productions across several trials (Treisman, 1963). This corresponds to the "variable error" in terms of Fechner (1860). However, only few studies (e.g., Oberfeld et al., 2014) analyzed the variable error, and for this reason we restricted our meta-analysis to the mean duration of the time estimates (constant error) for tasks (a) to (c). Several studies additionally asked for ratings of the subjects' experience of the flow of time (task (e)), often by means of visual analogue scales (VAS; e.g., Bschor et al., 2004; Mundt et al., 1998; Oberfeld et al., 2014) or questionnaires (Bech, 1975; Münzel et al., 1988). On visual analogue scales, the subjects are asked to mark a point on a line where the endpoints represent a very slow and very fast subjective flow of time. Notably, these ratings differ from tasks (a) to (d) because the subjective flow of time is assessed rather than the perception or production of defined time intervals.

Occasionally, effects of depression on other than the five tasks listed above have been studied. For instance, Bolbecker et al. (2011) measured the timing abilities of depressive patients by means of a paced finger tapping task, and Oberfeld et al. (2014) studied time-to-contact estimates for approaching visual objects (cf. Regan and Gray, 2000). However, these additional tasks have not been investigated in more than two primary studies each, and were therefore not included in our meta-analysis.

In order to predict in which way depression might influence the performance on the experimental tasks, it seems sensible to consider the influential cognitive *pacemaker–accumulator models* of interval timing (Gibbon et al., 1984; Treisman, 1963). These models assume an *internal clock* consisting of a pacemaker emitting pulses and an accumulator (or counter) collecting these pulses. In *Scalar Expectancy Theory* (*SET*), which is one of the most prominent pacemaker–accumulator models (Gibbon et al., 1984; Meck, 1996), this clock device is integrated into an information processing framework that encompasses memory and decision stages. According to SET, as soon as a subject begins to process an interval, an attentionally modulated switch between pacemaker and accumulator closes. Therefore, the clock pulses emitted by the pacemaker can reach the accumulator, which starts to 'count' these pulses. The more pulses being accumulated, the longer the perceived length of an interval. This means that if the subject's clock runs faster, more pulses get accumulated within a specified interval, and therefore the interval is perceived as longer compared to a subject with a slower clock speed.

In terms of this model, the observation that depressive patients frequently report to perceive time as going by less quickly can be explained by a faster running clock in depressive patients than in non-depressive controls. This assumption leads to precise predictions of performance differences between depressives and healthy control subjects in some of the interval timing tasks introduced above (Msetfi et al., 2012). For example, if the *verbal estimation* of a presented time interval in time units like seconds or minutes is required, according to the notion of an accelerated internal clock, the depressives accumulate more pulses during the presentation of the to-be-judged time interval, and hence produce higher estimates of the duration of the interval compared to control subjects. The opposite relation is predicted for a *production* task where the task is to produce an interval specified in time units, for example by marking its beginning and end by finger taps. If the internal clock runs at a faster pace, then the depressive patients should produce shorter intervals than the control subjects. According to the internal clock model, the subject starts to accumulate clock pulses at the first tap, and produces the second tap as soon as the accumulated number of pulses reaches a value (stored in long term memory) corresponding to for example "2 s". Due to the faster-running clock, the depressive patients should decide to mark the end of the interval at an earlier point in time than the control subjects. In a *reproduction* task, subjects are required to reproduce a previously presented time interval, for example by pressing a button to mark the interval's beginning and end. In contrast to *production* tasks, the interval is not specified in terms of time units but it is presented explicitly before the subject is asked to reproduce it. Here, a faster accumulation of pulses should affect