Time Perception and Depression Symptoms: A Perceived Delay Cues Feelings of
Hopelessness

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Abstract

The relationship between time perception and affect is bidirectional: Negative affective states tend to dilate (i.e., expand or slow) perceived duration, and unexpected delays (i.e., expanded durations) can induce negative affect like boredom or frustration. However, when studying time perception in affective disorders like depression, the direction of effect is typically viewed in terms of how affect, emotion or mood distort time perception. This experimental study reverses the direction of effect by showing that an experimentally-induced and unexpected expansion of time (i.e., “delay” condition) can increase reported levels of hopelessness, a symptom of depression. After a brief time production task, non-depressed participants who had been randomly allocated longer second than first intervals (i.e., an experimentally cued “delay”) reported higher levels of subsequent hopelessness. This was especially true for their “feelings about the future”, a subscale of the Beck Hopelessness Scale. It is proposed that the “delay” effect occurred where feelings of frustration or boredom with short-term present experience were generalized to the long-term expected future. Increased hopelessness after an unexpected delay is thought to be the result of a change in hierarchical Bayesian inference. A change in lower-order statistical reasoning about the present timing task affected higher-order abstract reasoning about the future. This suggests a potentially modifiable link between time perception and a common symptom of depression.

Keywords: Depression, time perception, hopelessness, Bayesian inference, time production, prediction error minimization.

Public significance statement

This study suggests that subtle, unexpected changes in time perception can alter someone's emotional state and hopefulness for the future. Whether in a clinical treatment environment or the broader context of day-to-day living, people at increased risk of depressive mental states or suicidality may gain therapeutic benefit from training in time perception or temporal expectancy management.

Time Perception in Depression Symptoms: A Perceived Delay Cues Feelings of Hopelessness

Decades of experimental research have shown a bidirectional link between emotion and time perception (Angrilli, Cherubini, Pavese, & Manfredini, 1997; Droit-Volet & Meck, 2007; Effron, Niedenthal, Gil, & Droit-Volet, 2006; Gil & Droit-Volet, 2012; Mella, Conty, & Pouthas, 2011). One consistent finding, which accords with the adage “time flies when you’re having fun”, is that negative emotion tends to slow, or dilate, perceived time (Tipples, 2008). When temporal expectations are violated, such as when an interval lasts longer than anticipated, perception is also slowed (Thomas & Handley, 2008). Negative emotional states like frustration (Tipples, 2018) and boredom (Danckert & Allman, 2005; Zakay, 2014) combine these effects when one is frustrated or bored while waiting longer than expected for something to happen. There is a close interdependence between intervals that are unexpectedly long, negative emotions, and slowed time perception.

The current paper examines tests this interdependence in the context of emotional disorder, specifically symptoms of depression. Many previous studies have assessed how people diagnosed with depression perceive time and, although experimental effects depend on methodology, meta-analytic evidence confirms that they tend to perceive time as passing more slowly (Thönes & Oberfeld, 2015). Not to be confused with absolute (ms/s/min etc) or relative (longer versus shorter) interval *duration* judgements, time *passage* judgements refer to the subjective appraisal of the relative rate (i.e., slow versus fast) of perceived temporal flow (Thönes & Stocker, 2019). Despite the methodological distinction regarding how time is judged, slowed time passage in depression, called “time dilation” (Kitamura & Kumar, 1982; Stanghellini et al., 2017), may be associated with under- and over-estimation of durations depending on the interval being judged (Kent, Van Doorn, & Klein, 2019).

This study reverses the more commonly conceived direction of the effect by assessing whether time perception, especially a feature called ‘temporal expectancy’, affects symptoms

of depression in non-depressed individuals (i.e., a non-clinical sample with a range of depression symptom severity). A recent study (Kent, Van Doorn, Hohwy, & Klein, 2019) showed that hopelessness, a key clinical symptom of depression and suicide risk (American Psychiatric Association, 2013), increased when people experienced an experimentally cued “delay” (i.e., participants exposed to a second interval duration that was unexpectedly longer than the first). Given the potential implications of these findings, here we further interrogate Kent et al.’s (2019) results in order to understand which facets of hopelessness are prone to the “delay” effect. No new data has been collected but further granular analyses have been performed to examine the data in more detail.

It is worth noting that nine of the twenty items comprising the most widely used clinical measure of hopelessness, the Beck Hopelessness Scale (BHS; Beck, Weissman, Lester, & Trexler, 1974), were derived from a test assessing an individual’s thoughts about their (distal) future. The study by Kent, Van Doorn, Hohwy, et al. (2019) found that randomly delaying the *proximal* future changed how hopeful people perceived their *distal* future to be. Thus, under the right experimental conditions, an effect of time perception on depression, rather than the traditional effect of depression on time perception, became evident.

Kent, Van Doorn, Hohwy, et al. (2019) explained the effect in terms of Bayesian statistical inference whereby the length of the first interval became the “expected” or “standard” length, known as the prior distribution, relative to which the second interval was judged as either short/not delayed or unexpectedly long/delayed (Shi, Church, & Meck, 2013). Like other mental states of negative valence such as boredom (Zakay, 2014) and frustration (Tipples, 2018), hopelessness was correlated with time dilation and so a three-way interrelationship between interval duration (i.e., temporal expectancy), time perception, and a symptom of depression was demonstrated experimentally.

In order to better understand this “delay” effect, the current paper analyses the Kent et al. (2019) results in more detail by investigating subscales of the BHS and individual participant data. Given that delays are associated with affective changes in present experiences (Sackett, Meyvis, Nelson, Converse, & Sackett, 2010), it was expected that “Feelings about the future” (i.e., the affective subscale) would be the subscale most prone to the “delay” effect. Specifically, it was expected that a “delay” would increase participants’ hopelessness in relation to their “feelings about the future”. It was also expected that individuals who reported similar levels of hopelessness on a depression symptom screening questionnaire prior to the time production tasks would differ in their subsequent “feelings about the future” after the time production tasks depending on whether they were exposed to a “delay” between the first and second intervals, or a control (i.e., no delay) condition.

Method

Participants

Exclusion criteria included insomnia, drug or alcohol dependence, impaired cognitive processing speed, and visual impairment. One individual was excluded on these bases prior to participating. Six participants with missing BHS data and two participants with missing interval production data were also excluded from the analysis. The final sample submitted for analysis comprised 56 people (31 females) whose ages ranged from 17 to 55 years ($M = 34.42$ years, $SD = 6.96$). Overall, pre-screening scores on the Patient Health Questionnaire 9-item (PHQ-9) indicated that two participants experienced “moderate”, while another participant experienced “moderately severe”, symptoms of depression. These individuals’ data were included because, as shown below, their inclusion did not alter the outcomes of the analyses. The sample therefore represents a range of depressive symptom severity from “none” or “low” to “moderately severe”.

Materials

Electronic materials were displayed on a 21" Apple iMac (2011) or 13" MacBook Pro (2013) via an internet browser (Safari, Chrome, or Firefox). The PHQ-9 screened for depression symptoms over the previous two-weeks by asking people to report the frequency of experiences including "feeling down, depressed or hopeless" on four-point Likert-type scales of frequency (i.e., "Not at all", "Several days", "More than half the days", and "Nearly every day")(Kroenke, Spitzer, & Williams, 2001). The PHQ-9 demonstrated good internal consistency (Cronbach's $\alpha = 0.82$) in the current sample.

The 20-item BHS assessed levels of hopelessness over the preceding week (i.e., states) using true/false responses (Beck et al., 1974). The BHS comprises three subscales termed "feelings about the future" (five items such as "I look forward to the future with hope and enthusiasm"), "loss of motivation" (eight items such as "I might as well give up because I can't make things better for myself"), and "future expectations" (five items such as "I can't imagine what my life would be like in 10 years")(Beck et al., 1974). The BHS showed poor internal consistency ($\alpha = 0.57$) which could, however, be a consequence of the effect induced by the time production task (see Discussion).

Procedure

In line with Human Research Ethics Committee clearance (A15-105) from Federation University, participants read a plain language statement and provided written consent prior to participation. No reimbursement was offered for participation. Demographic information and heart-rate variability measures were collected before participants completed the PHQ and other screening tests for anxiety symptoms (Generalised Anxiety Disorder 7-item, GAD-7) (Spitzer, Kroenke, Williams, & Löwe, 2006), insomnia (Insomnia Severity Index, ISI)(Bastien, Vallières, & Morin, 2001), alcohol and illicit drug use (Cut-down, Annoyed, Guilty, and Eye-opener Alcohol Illicit Drug, CAGE-AID)(Bush, Shaw, Cleary, Delbanco, & Aronson, 1987), and cognitive processing speed (Trail Making Test, Part A)(Reitan, 1958).

Heart-rate variability and screening tests besides the PHQ-9 do not feature in the current analysis.

Time perception measures were then administered where participants indicated how quickly or slowly they had experienced time on the day of the experiment. Here, a 100 mm visual analogue scale (VAS) displaying “very slow” at the bottom and “very fast” at the top was used. After this time experience measure, participants were instructed to produce six, randomly ordered intervals (i.e., random presentation of 10, 20, 30, 40, 60 and 90 s) by clicking “start” and “stop” icons on a computer screen. Although there are a multitude of ways to assess interval duration judgement, and different methods produce seemingly contradictory results, here we focused exclusively on interval production tasks. We have done so because they are particularly sensitive to whether attention is being paid to time or some other concurrent task (Zakay & Shub, 1998). This distinction between cognitive load and production of intervals relevant to working memory activity is also theoretically important for time perception in depression research (Kent, Van Doorn, & Klein, 2019). Production methods require individuals to manually judge duration by indicating the start and/or end of a target interval, which is different from verbally estimating an interval (i.e., passively judging interval length in seconds or minutes), or even reproducing an interval that has been presented previously.

Participants were advised that counting was allowed. In order to probe the temporal expectancy effects of experimental “delay” and “acceleration”, intervals were produced once only and no practice intervals were offered. Although repetition or averaging across multiple trials of the same interval is common in time perception research (Oberfeld, Thönes, Palayoor, & Hecht, 2014; Sévigny, Everett, & Grondin, 2003), a precise estimate of the participants’ judgement of the interval was not required for current purposes. Inclusion of practice intervals could also have masked the temporal expectancy “delay” effect which is

theorised to occur when the second interval is longer than the first (Jones & Boltz, 1989; Sucala & David, 2012). Following the time production tasks, participants then filled out an online version of the BHS.

Statistical analyses

To test the hypothesis that the “delay” condition may elicit negative “feelings about the future”, Bayes Factors were computed to represent to weigh evidence for different models. Bayesian statistical analysis quantifies how much more likely one particular model is compared to others, including the null hypothesis (Dienes, 2011). A Bayes Factor of $BF_{10} = 10$, for example, indicates that the model under consideration is ten times more likely than the null. Using a system devised by Jeffreys (1998), a BF_{10} between 2 and 10 is interpreted as substantial evidence for the model in question, a $BF_{10} > 10$ is interpreted as strong evidence, and a $BF_{10} > 100$ is interpreted as decisive evidence.

In each of the Bayesian ANCOVA's, extraneous variance from time experience (i.e., fast versus slow), duration judgement (i.e., slope of interval productions), and pre-test depression symptoms (i.e., PHQ-9 scores) were controlled so as to isolate the “delay” effect from other sources of temporal and mood variation. Participants were grouped according to whether their second interval productions were randomly assigned to be longer (“Delay” condition, $N = 26$) or shorter (“No Delay” condition, $N = 30$) than the first. If a participant was randomly allocated a first interval of 10 s and a second interval of 20 s or more, they were assigned to the “Delay” condition. Alternatively, if they were randomly allocated a first interval of 90 s and a second interval of 60 s or less, they were assigned to the “No Delay” condition. The remaining four intervals were also varied randomly but, as found by Kent et al. (2019), the random presentation of intervals three to six did not affect the level of hopelessness reported after the time production task.

In a second analysis, participants were grouped according to whether their second interval productions were (a) more than 30 s longer than the first interval (Large Delay, $N = 17$), (b) more than 30 s shorter than the first interval (Large Acceleration, $N = 21$), or (c) less than 30 s longer or shorter than the first (Intermediate, $N = 18$). For example, if they were randomly allocated a first interval of 90 s and a second interval of 40 s or less, they were assigned to the “Large Acceleration” condition. Alternatively, if they were allocated a first interval of 20 s and a second interval of 60 s or more, they were assigned to the “Large Delay” condition, for example. If a participant was randomly allocated a first interval of 20 s and a second interval of 40 s, they were assigned to the “Intermediate” condition.

Results

As shown in Table 1, interval productions were highly variable between participants, but also highly linear (i.e., a plot of individual responses from shorter-to-longer interval durations yielded an approximately linear trendline). In terms of the “delay” effect on symptoms of hopelessness, Figure 1 shows Bayesian ANCOVA posterior distributions and Bayes Factors for each of the BHS and its subscales when controlling for pre-test PHQ-9 scores, time experience (i.e., fast or slow if above or below the midpoint of the VAS, respectively), and duration judgement (i.e., central tendency of production tasks above or below one), and for each of the two group-wise comparisons (Delay or No Delay; Large Acceleration, Intermediate, or Large Delay conditions).

These results show substantial evidence to support an experimentally-induced difference in overall BHS hopelessness scores between groups, whether or not the sample is submitted to a two- (Delay and No Delay; $BF_{10} = 2.47$) or three-way (Large Acceleration, Intermediate, and Large Delay; $BF_{10} = 2.58$) split. There is also strong evidence that this induction is due primarily to changes in the BHS subscale “feelings about the future” when a two-way sample split is performed ($BF_{10} = 10.30$), and substantial evidence for the three-way

split ($BF_{10} = 5.74$). There is no evidence that the other subscales (“loss of motivation” and “future expectations”) underwent similar experimental changes, given that distributions are overlapping to a greater extent and Bayes Factors are all less than one.

In addition to other time-related variables such as slope and dilation, these results controlled for the level of depression symptoms prior to the time production task. To exemplify this distinction between experimental effects and individual differences, only two participants reported feeling “down, depressed or hopeless” for “more than half the days” over the preceding two weeks for item 2 of the pre-test PHQ-9 (i.e., none reported “nearly every day”). One participant (X) scored 16/27 or “moderately severe” for depressive symptoms overall, while the other participant (Y) scored 11/27 or “moderate” for depressive symptoms. Post-screening, participant X was randomly assigned a second interval 50 s shorter (i.e., Large Acceleration condition) than the first and then scored zero (0) for BHS “feelings about the future”. In contrast, participant Y was randomly assigned a second interval 80 s longer (i.e., Large Delay condition) than the first and then scored two (2), or approximately two SDs above the mean, for BHS “feelings about the future”. Though anecdotal, this suggests a Large Acceleration decreased a facet of hopelessness for participant X, while a Large Delay increased a facet of hopelessness for participant Y. Their overall hopelessness scores were similarly affected (i.e., BHS score of three [3] or approximately average for participant X versus seven [7] or 2.5 SDs above average for participant Y).

Discussion

Results suggest that a perceived delay in the timing of events presently attended to, such as a controlled time production task, may alter how people perceive the future. This finding is broadly consistent with extant literature on the emotional effects of interval timing and time perception (Droit-Volet & Meck, 2007; Gil & Droit-Volet, 2012; Wittmann & van Wassenhove, 2010), except that it reverses the traditional direction of effect by showing how

time can distort emotion, as opposed to how emotion can distort perceptions of time. The key variable linking time and emotion is temporal expectancy. When intervals are longer than expected, negativity and time dilation occur simultaneously. The key experimental variable was the relative length of first and second intervals, and the key dependent variable was (most likely) an affective subscale factor of hopelessness called “feelings about the future”. This study reinforces the finding by Kent, Van Doorn, Hohwy, et al. (2019) that, under controlled experimental conditions, feelings of hopelessness can be manipulated by a simple time perception task.

It has been convincingly argued that Bayesian optimization, where prior experience informs predictions about the future, occurs during the performance of timing tasks (Gu, Jurkowski, Shi, & Meck, 2016; Jazayeri & Shadlen, 2010). As above, prior experience (expectation) of a relatively short first interval affects how people perceive a relatively long second interval. Hohwy, Paton, and Palmer (2016) also proposed a hierarchical Bayesian framework for time dilation effects called “distrusting the present”. The hierarchical component explains how prior experience integrates over lower-order, relatively short timescales up to higher-order, relatively long timescales. The current findings suggest that affective changes experienced over short timescales within the context of a time production task (e.g., frustration or boredom due to a 30 s “delay” effect) feed up the Bayesian hierarchy to change how people feel about longer timescales (e.g., weeks, months, years).

The hierarchical Bayesian Predictive Processing (PP) account also helps to explain why people diagnosed with depression, although experiencing time as passing slowly (sometimes extremely so), demonstrate only mild and selective impairments on interval judgement tasks such as the production task outlined above. As discussed by Kent, Van Doorn, and Klein (2019), there is a discrepancy between performance and judgement of shorter and longer intervals. Production of shorter intervals connected to immediate conscious

experience are judged as “long” or “slow”, but longer intervals from memory are judged as “short” or “fast”. This difference between “short and slow” and “long and fast” is itself due to the timescale involved, and so when an interval that was expected to be short is in fact long, slowness becomes uncomfortable in the same way that unexpectedly long intervals can be frustrating or boring. This shows depression is not a special case of distorted time perception, but rather an extension of continuous “normal” temporal functioning that varies on non-orthogonal experiential (flow to dilation) and affective (positive to negative) dimensions.

These findings could also add to the contemporary debate about whether hierarchical Bayesian frameworks of predictive processing, the free energy principle, predictive coding and perceptual/active inference can explain affected-biased attention, decision-making and expectations about rewards or punishments (Ransom et al., 2020). When participants unexpectedly encountered a delayed interval, this would have likewise delayed the goal-directed behaviour associated with performing the time production task, which is a reward of sorts. The delay in itself is therefore a (very mild) form of punishment and so a negative emotional response is experienced, in this case in the form of reduced expectation of future rewards (i.e., hopelessness). This shows that, in terms of hierarchical Bayesian perceptual inference, and in the case of the link between emotion, time perception, and expectation, there is also a decision-making element akin to ‘delay discounting’ in that the value of future rewards is discounted as compared to immediate rewards (Wittmann, Lovero, Lane, & Paulus, 2010). Previous research shows that anhedonia, a key symptom of depression tied to the lack of sensitivity to immediate rewards, is associated with reduced delay discounting, meaning that the value of longer-term rewards is increased (Lempert & Pizzagalli, 2010). Hopelessness and anhedonia may thus represent distinct processes underlying depressive aetiology, with hopelessness representing the initial affective response to delayed rewards, and anhedonia the subsequent cognitive reappraisal of delayed rewards. Measuring time perception and

symptoms of depression is a way to tease apart these variables to show how they interact with models of hierarchical Bayesian inference.

This reasoning also supports the interpretation that the the observed “delay” effect was not due to the influence of pre-existing levels of hopelessness as measured by the PHQ-9, and so an experimental effect can be inferred with some confidence despite the lack of pre- and post-testing using the same instrument (i.e., the BHS, which is not a validated measure of transient experimental effects). The modifiable link between immediate experience and longer-term mental states could be replicated in a larger study, perhaps using a clinical sample, to investigate the overall effect of hopelessness and address the low internal consistency of the BHS.

Although the present study is potentially limited by low internal consistency of the BHS, which may be a consequence of the experimentally-induced change to a subset of items related to “feelings about the future”, it is consistent with other contemporary time perception research demonstrating a link between temporal accelerations and physiological and psychological parameters (e.g., fatigue, hunger, and pain perception) (Thönes, Arnau, & Wascher, 2018). As well as depression affecting time perception (Thönes & Oberfeld, 2015), it appears that time perception can also affect a symptom of depression.

An interesting possibility for future research is the extent to which these effects can be used therapeutically to address hopelessness, depression and suicidality in clinical or preventative settings. Transient effects of severely depressed mood may be alleviated by reversing the “delay” effect or, as a longer-term preventative measure, education or training in time perception awareness and management techniques could help avoid the automatic negative association between temporal expectancies and emotional experience.

In summary, it is known that depression (Thönes & Oberfeld, 2015), boredom (Zakay, 2014), and frustration (Tipples, 2018) commonly associate with time dilation. The current

experimental study shows that this relationship is bidirectional, highly sensitive to temporal expectancy, explicable in terms of a Bayesian hierarchy related to predictive processing, and potentially useful in an applied setting to help people attenuate transient or even avoid long-term disposition towards feelings of hopelessness.

Author contributions

Author L. Kent designed the study, conducted the experiment, undertook the statistical analyses, and drafted the manuscript. Authors G. Van Doorn and B. Klein provided academic supervision and contributed to the manuscript. Author J. Hohwy contributed to the manuscript. All authors have approved the final manuscript.

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Table 1

Ranges, means and standard deviations of time productions, linearity, depression symptoms and hopelessness (BHS and subscales).

Variable	Min.	Max.	<i>M</i>	<i>SD</i>
10 s production (s)	5	22	11.41	3.48
20 s production (s)	10	68	23.59	9.72
30 s production (s)	20	81	35.68	12.27
40 s production (s)	21	103	48.24	16.47
60 s production (s)	37	144	73.43	22.70
90 s production (s)	57.6	207	111.52	33.93
Linearity (R^2)	0.92	1	0.98	0.02
Depression (PHQ-9 raw score)	0	16	3.30	3.41
Hopelessness (BHS raw score)	0	8	2.29	1.90
“Feelings about the future” (raw score)	0	3	0.59	0.78
“Loss of motivation” (raw score)	0	2	0.21	0.46
“Future expectations” (raw score)	0	4	1.05	1.05

Figure 1

Bayesian ANCOVA posterior distributions and Bayes Factors (BF) for groups assigned to Delay (D) or No Delay (ND) conditions (top row), and Large Delay (LD), Intermediate (INT) or Large Acceleration (LA) conditions (bottom row) across overall BHS hopelessness score (far left column) and three BHS subscales (three right-hand columns).

Note: Vertical axes indicate probability density and horizontal axes indicate distribution variance around standardised values of the scale/subscale.