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SHORT COMMUNICATION

How does positive mood modulate time-based event expectancy?

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Abstract

In the present study, we investigated how positive mood affects the formation of time-based event expectancies. After positive or neutral mood inductions, participants performed a binary choice response task in which two target stimuli (circle and square) and two pre-target intervals (800 and 1600 ms) appeared equally often. One of the targets was paired with the short interval and the other target with the long interval in 90% of the trials. We found that participants from the positive and neutral groups showed markedly different behavioral patterns of time-based expectancy. The time-based expectancy was restricted to shorter intervals for the positive group and to longer intervals for the neutral group. We propose that positive mood increases attentional prioritization of information that is temporally closer to us.

Keywords Positive mood · Time-based expectancy · Associative learning · Attentional broadening

Introduction

When delays in our environment are predictive with regard to subsequent events, humans can implicitly adapt to this regularity (Kunchulia and Thomaschke 2016; Thomaschke and Haering 2014; Thomaschke et al. 2015). This adaptation is referred to as time-based expectancy and is a new, but fast growing, research field in cognitive psychology (see Thomaschke and Dreisbach 2015, for a review). Time-based event expectancy is important in many types of interaction with the environment (Aufschnaiter et al. 2018a, b; Aufschnaiter et al. 2018a, b; Shahar et al. 2012; Thomaschke and Haering, 2014) as well as in verbal communication (Roberts and Francis 2013; Roberts et al. 2011; Roberts and Norris 2016).

Note that, time-based expectancy is different from time expectancy, also referred to as temporal attention (Correa et al. 2006; Coull et al. 2000; Seibold et al. 2011) or temporal expectancy (Coull 2009). In time expectancy, individuals are trained or cued to direct their attention (or preparedness) to a certain point in time. Thus, they expect the upcoming event to occur at, for example, rather 1000 ms than 500 ms. Yet, in temporal attention paradigms, the possible events are typically evenly distributed over points in time (Bausenhart et al. 2007; Correa et al. 2005). Thus individuals are trained or cued to expect all possible event with higher probability at, for example, 1000 ms than at 500 ms.

In time-based expectancy, on the contrary, individuals do not expect a certain point in time as such. In studies on time-based expectancy, event occurrence is typically equally likely at each point in time (Thomaschke and Haering, 2014; Thomaschke et al. 2016; Volberg and Thomaschke 2017). Yet, events are unequally distributed over points in time, allowing participants to expect event conditional upon time. Consequently, time-based expectancy is not expectancy for time, but expectancy for events based on time.

Recently, time-based expectancy has also been investigated in the domain of emotion processing. The emotional valence of an event is temporally predictable in many real-life scenarios. When, for example, we wait for a system to complete some process such as saving or accessing files, sending emails, or establishing the connection to a network, unusually long waiting durations change our expectations from positive (i.e., successful completing the process) to negative (i.e., failure to complete the process, see e.g.,

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Shahar et al. 2012). Furthermore, it has been shown that the duration of the silent gap between two conversation partners' turns affects the expectation for a positive or negative answer in response to requests (Roberts and Francis 2013; Roberts et al. 2011; Roberts and Norris 2016). A recent study by Thomaschke et al. (2018) found that we rapidly and implicitly adapt to time-based affect predictability. They asked participants to categorize the grammatical gender of irrelevantly positive and negative words, with the positive or negative valence being predictable by the duration of a pre-target interval. Participants showed better performance for expected combinations of interval and valence relative to unexpected ones, suggesting that time-based expectancy could be directed at processing task-irrelevant affective aspects of a target (Thomaschke et al. 2018). However, to date, emotion has only been investigated as the target of time-based expectancy, in the sense that one expects a certain emotional aspect after a particular interval. Whether emotion can also affect the formation of time-based expectancy in a more general sense remains unexplored. In particular, it is unknown whether emotional states can affect the formation of time-based expectancy in general, including expectancy for non-emotional aspects of a target.

In everyday life, our emotional mood often affects our cognitive ability. Studies showed that positive and negative mood could profoundly influence our cognition in several domains (Becker and Leinenger 2011; Droit-Volet et al. 2011; Fröber and Dreisbach 2012; Lagner et al. 2014; Phillips et al. 2002). Mood, for instance, changes our creative abilities (Isen et al. 1987), influences working memory (Mitchell and Philips 2007) and affects attention (Vanlessen et al. 2014). Recent evidence suggests that mood effects cognitive control, for example, positive affect reduces proactive control (i.e., preparatory control) while it increases reactive control (i.e., just in time control, see Fröber and Dreisbach 2014). Our emotional mood can also influence temporal cognition such as, for example, our time perception ability (Droit-Volet and Meck 2007; Corke et al. 2018). Studies by Gebauer et al. (2008) showed that also temporal distance perceptions could be affected by mood congruence. For example, chronically happy people perceive a recalled positive self as temporally more recent than a recalled negative self (Gebauer et al. (2008).

However, it is not clear yet, how our experience of mood modulates our ability to form time-based expectancy.

In the present study, we investigate how positive mood affects our ability to form time-based expectancies for valence-neutral targets. After positive or neutral mood inductions, participants performed a time–event correlation paradigm in which one of the targets (circle or square) was paired with a short pre-target interval and the other target with a long interval in 90% of the trials. In this paradigm, the formation of time-based event expectancy typically leads to faster responses to frequent interval—target combinations (i.e., when the target was predicted by the duration of the pre-target interval with 90% probability), relative to infrequent ones (i.e., when target was predicted by the duration of the pre-target interval by only 10% probability; see Thomaschke et al. 2015; Kunchulia and Thomaschke 2016; Thomaschke et al. 2011). This effect is typically interpreted in the way that the surprise about a target which is atypical for the current point in time causes response time costs, thereby indirectly evidencing time-based expectancy (Aufschnaiter et al. 2020).

Previous studies have shown that time-based expectancy relies on relative (as opposed to absolute) time representations and that participants associate the stimulus–response events with the binary categories "early"/"late" (Kunchulia and Thomaschke 2016; Thomaschke et al. 2015). In young healthy adults, the formation of time-based expectancy was in some previous studies restricted to the pre-target interval that was associated with the "late" category i.e., with the relatively longer interval of the present pair of intervals irrespective of its absolute duration (Kunchulia et al. 2019; Thomaschke et al. 2015). This means participants expected at the longer interval the event that indeed occurred more often after the long interval, but at the shorter interval, they seemed to expect both events with equal probability, though at the shorter interval also one of the event was presented more often than the other. Thus, participants were less sensitive to time-dependent event probabilities at the short interval than at the long interval. Note that, a similar effect—stronger expectancy at the long relative to the short interval—has also been observed for temporal attention (Delogu et al. 2019). The aim of the current study is to investigate, whether mood induction does affect this pattern.

Positive mood has been found to shift the focus of cognitive processing. According to the broaden-and-build theory positive emotions such as, for example, interest, joy, contentment, and love broaden our momentary thought-action repertoire that promote discovery of novel and creative actions, ideas, and social bonds (Fredrickson 2004). Consequently, under positive mood the processing of global information is facilitated whereas local information is inhibited (Gasper and Clore 2002). However, some studies suggest that positive mood may also facilitate more systematic, narrow processing (Das and Fenns 2008). For example, positive mood promotes systematic processing of self-threatening information (Das and Fenns 2008). Likewise, positive mood induces a broadening of visual-spatial attention for stimuli that are closely related to the individual self when contrasted to not-self-related stimuli (e.g., Grol et al. 2014).

Here, we hypothesized that positive mood would enhance the formation of time-based expectancy for shorter intervals more strongly than for longer intervals. Positive mood broadens attention for stimuli that are closely related to the individual self. Transferring this logic to the temporal domain, one would speculate that positive mood would facilitate the processing of events that are temporally closer to us, that is, occurring after a short rather than a long interval.

Method

Participants

Thirty right-handed adults aged 18–31 years ($M=21.1$ years, $SD=2.9$; 16 females, 14 males) participated. All participants were randomly assigned to either a positive mood condition ($n=15$; 7 males; $M=21.7$ years, $SD=2.3$) or a neutral mood condition ($n=15$; 7 males; $M=20.5$ years, $SD=3.4$). To assess overall happiness, all participants completed a 4-item Subjective Happiness Scale (SHS; Lyubomirsky and Lepper 1999). Scores on the SHS did not differ significantly ($p=0.69$) between the neutral group ($M=4.27$, $SD=0.73$) and the positive group ($M=4.36$, $SD=0.63$), indicating there was no significant baseline difference in emotional and cognitive well-being. None of the participants reported a history of psychiatric or neurological disorders.

Participants were mostly students at the Free University of Tbilisi, and the study was carried out in accordance with the World Medical Association's Declaration of Helsinki. Participation was voluntary and written informed consent was obtained from all participants.

Apparatus and stimuli

E-Prime2 was used for running the experiment and collecting data (Schneider et al. 2002). Data were collected on a Windows PC with LCD display (screen resolution 1280 × 800 pixels). Participants responded by pressing the "Z" key of the computer keyboard with the left index figure and the "M" key of the computer keyboard with the right index finger. Target stimuli were an orange-filled circle and an orange-filled square (approximately 2 cm × 2 cm) presented on a black background. The fixation cross was a red font color "+" symbol (typeface "Arial", 1.3 cm × 1.3 cm). The stimuli were presented centrally on the screen.

Procedure

Participants performed a binary choice response task in which they had to press the "Z" key of the computer keyboard when the circle appeared and the "M" key when the square appeared. They were required to respond as fast and as accurately as possible. Each trial began with presentation of the fixation cross, which stayed on the screen for the duration of the long (1600 ms) or short (800 ms) pre-target interval or foreperiod (FP). After a short or long FP, the target stimulus was presented. For half of the participants, the short FP predicted the appearance of the circle stimulus and the long FP predicted the appearance of the square stimulus, with 90% validity. For the other half, this relation was inverted. Both target stimuli and FP occurred overall equally often.

Before the mood manipulation (see below), all participants completed a practice session with eight trials. After the mood induction procedure, they completed three experimental blocks comprising 80 (72 valid and 8 invalid) trials each (240 trials in total). In the valid trials, short or long FP duration validly predicted the target stimulus with a probability of 0.9. The invalid trials occurred with a probability of $p=0.1$ (see Fig. 1).

Mood induction

For mood induction, participants were asked to recall a past personal event: in the positive group, participants had to write about an event that made them feel happy up to now (for details, see: Becker and Leinenger 2011; Richter and Gendolla 2009); participants in the neutral group were asked to write about the usual events (ignoring unusual ones) of yesterday (Phillips et al. 2002). Participants had to perform this task for 5 min. Immediately after the mood induction procedure, all participants were asked to rate their present overall mood from very unpleasant to very pleasant, using a scale ranging from −10 to 10. A higher score indicated a more positive mood. After that, participants performed the binary choice response task described above.

Data analysis

To investigate the effect of positive mood on time-based expectancy, we conducted mixed analyses of variance (ANOVA) with Group (positive vs. neutral) as the between-subject factor and FP (short vs. long) and Validity (valid vs. invalid) as within-subject factors. Mean response time (RT) and mean error rate were analyzed as dependent variables. Error trials and trials with RTs deviating from the condition mean by more than three standard deviations were excluded from the RT analysis.

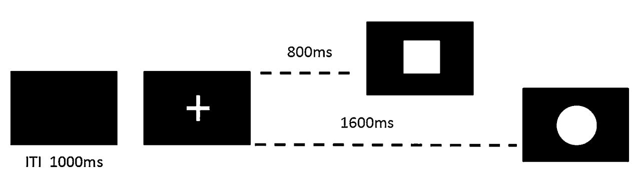

Fig. 1 Example of a trial structure. In the valid trial, short FP (800 ms) associated with the square and long FP (1600 ms) with the circle in 90% of their occurrence. The trials were separated by an inter-trial interval (ITI) of 1000 ms

To control whether the baseline emotional well-being could influence on observed effects, additionally, we run the analogous mixed ANCOVA entering SHS score as covariate.

We also conducted an exploratory correlational analysis between magnitude of the time-based expectancy effect and post-induction mood score.

The statistical significance was set at an alpha level of 0.05 for all tests.

Results

After mood induction manipulation, participants from the positive group on average showed a marginal non-significant tendency toward a higher overall mood score ($M = 7.1$, $SD = 1.9$) than participants from the neutral group ($M = 4.9$, $SD = 3.9$; $t(28) = 1.9$, $p = 0.068$), indicating a more positive feeling in the positive group.

A mixed analyses of variance (ANOVA) with Group (positive vs. neutral) as the between-subject factor and FP (short vs. long) and Validity (valid vs. invalid) as within-subject factors on RT showed a significant three-way interaction between Group, FP, and Validity [$F(1,28) = 6.89$, $p = 0.014$, $\eta^2_p = 0.2$]. Participants in the positive group showed an advantage for valid FP–target combinations, i.e. when target was validly predicted by FP duration ($M = 564$ ms, $SD = 113$), over invalid ones, i.e., when target was invalidly predicted ($M = 579$ ms, $SD = 111$), for the short but not the long FP (valid: $M = 563$ ms, $SD = 141$; invalid: $M = 549$ ms, $SD = 124$). On the contrary, participants from the neutral group showed an advantage for valid FP–target combinations ($M = 540$ ms, $SD = 113$) over invalid ones ($M = 570$ ms, $SD = 118$) for the long but not the short FP (valid: $M = 570$ ms, $SD = 108$; invalid: $M = 564$ ms, $SD = 98$) (see Fig. 2). There was a significant main effect for the within-subject factor of FP [$F(1,28) = 5.09$, $p = 0.032$, $\eta^2_p = 0.15$], indicating faster responses for long FPs ($M = 555$, $SD = 120$) than for short FPs ($M = 569$, $SD = 107$). No other interaction or main effect was significant. In an analogous mixed ANOVA on RT entering the SHS score as covariate, the three-way interaction remained significant [$F(1,27) = 5.78$, $p = 0.023$, $\eta^2_p = 0.17$], indicating that potential differences in baseline emotional well-being did not impact on the mood effect.

Follow-up t-tests for each group separately showed only a significant Validity effect for the neutral group at the long FP [$t(14) = 2.428$, $p = 0.029$]. For the positive group, the Validity effect was non-significant at the long FP [$t(14) = 1.14$, $p = 0.273$].

A mixed ANOVA with Group (positive vs. neutral) as the between-subject factor and FP (short vs. long) and Validity (valid vs. invalid) as within-subject factors on error rate showed a significant main effect for the within-subject factor of FP [$F(1,28) = 7.94$, $p = 0.009$, $\eta^2_p = 0.22$] and a marginal main effect for the within-subject factor of Validity [$F(1,28) = 3.19$, $p = 0.085$, $\eta^2_p = 0.10$]. There was a significant two-way interaction between the within-subject factors of Validity and FP [$F(1,28) = 8.42$, $p = 0.007$, $\eta^2_p = 0.23$]. No other interaction or main effect was significant.

Follow-up t-tests for the long and the short FP, for the positive group showed a numeric advantage of the valid combinations over the invalid ones, which was a marginal significant for the short FP, $t(14) = 2.27$, $p = 0.078$ (corrected), but not for the long FP, $t(14) = 0.203$, $p = 0.1.68$ (corrected). However, in the neutral group, there was no such significant effect for the short, $t(14) = 1.16$, $p = 0.264$ (corrected), or for the long FP, $t(14) = 0.27$, $p = 1.58$ (corrected)(Fig. 3).

At the short FP, a Pearson correlation test showed a significant positive correlation between the Validity effect magnitude on RT with mood score [$r(28) = 0.399$, $p = 0.029$], and between the Validity effect magnitude on error rate with mood score [$r(28) = 0.463$, $p = 0.01$]. At the long FP, no such correlation was observed [r(28) = 0.214, $p = 0.44$, for RTs, r(28) = 0.104, $p = 0.584$, for error rates].

Discussion

After inducing positive or neutral mood (in different groups), we tested the formation of time-based expectancy. Participants had to associate two choice responses with two different FPs (short and long). We found that participants from both groups performed better at valid target–FP combinations than at invalid ones, suggesting that

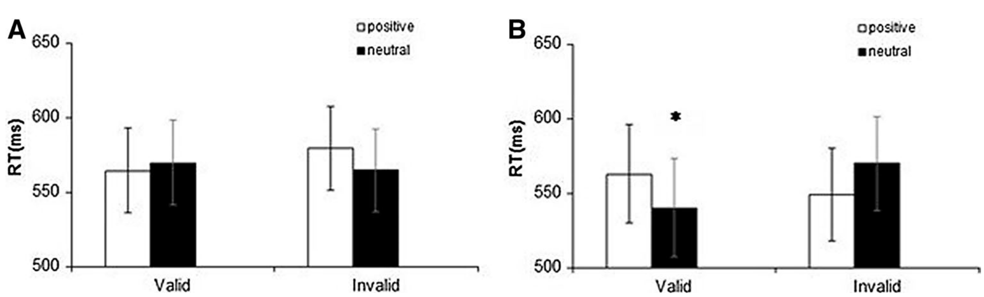

Fig. 2 Mean response times (RTs) for a choice response task: **A** at the short FP; **B** at the long FP. Error bars represent the standard error of the mean

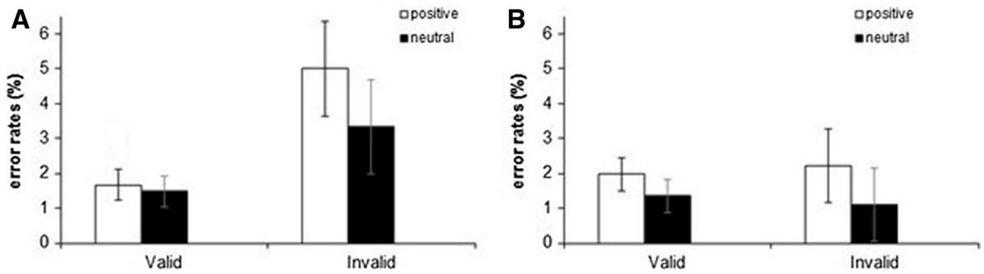

Fig. 3 Mean error rates for a choice response task: **A** at the short FP; **B** at the long FP. Error bars represent the standard error of the mean

both groups formed time-based expectancy. However, we found that participants in the positive and neutral groups showed markedly different behavioral patterns of time-based expectancy at least in RT: namely, time-based event expectancy was restricted to shorter FPs for the positive group and to longer FPs for the neutral group. Yet, the pattern was not present in error rates.

A pattern similar to the neutral group has been observed previously in studies with healthy young adults but with no mood induction. In those studies, time-based expectancy was more pronounced with the longer one of two FPs (Kunchulia et al. 2019; Thomaschke et al. 2015). We interpret this as an indication that neutral mood induction in the present study brought participants to a mood that is typical when participating in a cognitive psychology study without any special mood induction.

In contrast, for participants from the positive group the shorter FPs seem to be more optimal for making temporal predictions, suggesting that positive mood affects the formation of time-based expectancy. The result pattern confirms our hypothesis that positive mood seems to shift the cognitive focus toward closer points in time, that is, toward events after shorter rather than longer FPs. This cognitive focus, in turn, seems to facilitate the formation of associations between these close points in time and events. A potential mechanism could be linked to temporal attention. It is well known that temporal attention prioritizes information at specific points in time by enhancing a stimulus at a particular point in time and inhibiting other time points (Nobre and van Ede 2018; Fernandez et al. 2019; Recht et al. 2019). Previous studies have been reported that positive mood increases of visual-spatial attention for stimuli that are closely related to the individual self when contrasted to not-self-related stimuli (e.g., Grol et al. 2014). Analogously positive mood might induce a broadening of attention for events that are at closer points in time while inhibiting attention at distant points in time.

The finding from our study extends previous theorizing about changing cognitive focus shifts by mood to the temporal domain. Our finding also highlights the importance of taking into account participants' subjective mood states in temporal cognition research in general.

However, our study focused on only one single aspect among many other potential relations between mood and time-based expectancy. For instance, we neglected negative mood in the present design, which might have a similar or an inverse effect on time-based expectancy. Furthermore, we employed only affectively neutral target stimuli in the trials. An interesting question for future research would be to find out how congruence between globally induced mood and the individual trial's stimulus valence would impact the formation of time-based expectancy.

In conclusion, we found that positive mood modulates the formation of time-based expectancy, rendering shorter FPs more optimal for temporal expectancy. This modulation effect might be explained by attentional prioritization for information that is temporally closer to the individual. However, further studies are necessary to investigate the relation between positive mood and time-based expectancy in further detail.

Compliance with ethical standards

Conflict of interest No potential conflict of interest was reported by the authors.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the 1964 Helsinki declaration and with the ethical standards of the institutional and/or national research committee.

Informed consent Written informed consent was obtained from all participants included in the study.

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