You make me tired

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You make me tired: An experimental test of the role of interpersonal operant conditioning in fatigue

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ABSTRACT

Chronic fatigue is highly prevalent in the general population as well as in multiple chronic diseases and psychiatric disorders. Its etiology however remains poorly understood and cannot be explained by biological factors alone. Occurring in a psychosocial context, the experience and communication of fatigue may be shaped by social interactions. In particular, interpersonal operant conditioning may strengthen and perpetuate fatigue complaints. In this experiment, individuals (N = 44) repeatedly rated their currently experienced fatigue while engaging in cognitive effort (working memory task). Subtle social reward was given when fatigue increased relative to the previous rating; or disapproval when fatigue decreased. In the control condition, only neutral feedback was given. Although all participants became more fatigued during cognitive effort, interpersonal operant conditioning led to increased fatigue reporting relative to neutral feedback. This effect occurred independently of conscious awareness. Interestingly, the experimental condition also performed worse on the working memory task. Results suggest that fatigue complaints (and cognitive performance) may become controlled by their consequences such as social reward, and not exclusively by their antecedents such as effort. Results have implications for treatment development and suggest that interpersonal operant conditioning may contribute to fatigue becoming a chronic symptom.

1. Introduction

Humans frequently experience fatigue, for instance after physical and cognitive effort, prolonged wakefulness, stressful situations, and in acute illness. Although usually alleviated after a period of resting or recovery, fatigue may also persist over longer time periods and may lose its association with effort, illness, or resting. Epidemiological studies estimate that 2%–11% of the general population report long-term or chronic fatigue (lasting at least six months; Jason et al., 1999; Kluger, Krupp, & Enoka, 2013; Loge, Ekeberg, & Kaasa, 1998). In one large study (N = 9375) this estimate was even 31% of the general population, possibly due to over half of individuals with long-term fatigue in this sample suffering from a medical condition that may partially explain fatigue symptoms (van 't Leven, Zielhuis, van der Meer, Verbeek, & Bleijenberg, 2009). Indeed, fatigue is also one of the most common symptoms in chronic illness, including cardiovascular, neurological, and immunological diseases (Cumming, Packer, Kramer, & English, 2016; Heesen et al., 2006; Kluger et al., 2013; Stebbings & Treharne, 2010); several psychiatric disorders such as major depressive disorder, generalized anxiety disorder, somatic symptom disorder and attention deficit hyperactivity disorder (Rogers, Dittner, Rimes, & Chalder, 2017); and is a core symptom in chronic fatigue syndrome and fibromyalgia.

Nevertheless, our understanding of the processes that cause and maintain fatigue is largely incomplete. For instance, fatigue and other somatic sensations such as pain or dyspnea may exist in absence of bottom-up physiological or neurobiological dysregulation (Brown, 2004; Rief & Broadbent, 2007). The observation that there is often no simple correspondence between objective physiology and the conscious experience of somatic sensations calls for an integrative approach to illness and health; incorporating biological, psychological, and social processes (Lenaert, Boddez, Vlaeyen, & van Heugten, 2018; Van den Bergh, Witthöft, Petersen, & Brown, 2017). Several variables have indeed been implicated in the etiology of chronic fatigue, including neurobiological and disease specific variables (e.g., Chaudhuri & Behan, 2004; Pardini, Bonzano, Mancardi, & Roccatagliata, 2010), psychological variables such negative or catastrophizing thoughts about fatigue (e.g., Knoop, Prins, Moss-Morris, & Bleijenberg, 2010; Lukkahatai & Saligan, 2013), and environmental factors such as the presence of prolonged stressors (e.g., Wyller, Eriksen, & Malterud, 2009). With

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respect to social processes, there is increasing evidence that fatigue severity and fatigue related disability may be associated with the behavior of significant others of patients with chronic fatigue symptoms (Band, Wearden, & Barrowclough, 2015). For instance, perceived solicitous behavior by significant others has been related to higher fatigue severity and bodily pain among patients with chronic fatigue syndrome (Schmaling, Smith, & Buchwald, 2000), as well as worse levels of disability (Romano, Jensen, Schmaling, Hops, & Buchwald, 2009). Moreover, in a study that combined self-reported perceptions with direct observations of dyadic interactions, solicitous responses by the significant other were also found to predict reported and observed patient illness behaviors such as seeking help and verbally expressing fatigue and pain (Romano et al., 2009). These results indicate that interpersonal operant conditioning may play a role in the context of chronic fatigue. That is, fatigue and fatigue related behavior, such as resting or avoidance of activity, may constitute responses that are reinforced by their outcomes (e.g., temporary relief of fatigue; Lenaert et al., 2018). Similarly, expressing fatigue may be reinforced by receiving care and attention from significant others and health professionals. Reinforcement or reward by the social environment may maintain and strengthen fatigue reporting in the future, whereas it may decrease after social ‘punishment’ or disapproval (Domjan, 2005). Operant conditioning may thus help explain how reporting fatigue experiences can lose its association with effort or illness and their physiological correlates. Indeed, when successfully brought under operant control, fatigue reporting may become a function of its consequences (e.g., social reward/disapproval), rather than its antecedents (e.g., physical or cognitive effort; illness). Moreover, shaping of behavior by the social environment may be subtle, occurring in multiple interactions over longer time periods, and may therefore escape conscious awareness.

However, the currently available evidence for such operant conditioning account is based on cross-sectional studies, mainly relying on self-reported data about the perceived behavior of significant others (for a review: Band et al., 2015). This precludes conclusions about interpersonal operant conditioning as a (causal) mechanism in the development and maintenance of fatigue complaints. For instance, solicitous significant others may be inadvertently positively reinforcing and strengthening fatigue complaints. Alternatively, the presence of more severe fatigue symptoms may merely elicit more solicitous responding from significant others (Schmaling et al., 2000). Experimental research is necessary in order to assess the direction of this relationship. Surprisingly, there are no experimental studies on (interpersonal) operant conditioning in relation to fatigue. This is in strong contrast to pain research, where several experimental investigations have been based on Fordyce's (1976) theory that pain behaviors such as lying down, groaning, or wincing may be reinforced – and thus maintained – by its consequences, such as temporary relief of pain or attention from others. To the extent that the social environment rewards these pain responses, it may inadvertently contribute to the development of a pattern characterized by chronic pain and disability. In their seminal study, Linton and Götestam (1985) inflated a blood pressure cuff to a painful level on the arm of healthy individuals. Whereas cuff pressure remained constant throughout the experiment, subjective pain reports could be conditioned to increase/decrease by giving verbal praise/punishment to pain reports. Lousberg, Groenman, Schmidt, and Gielen (1996) showed that operant conditioning not only increased pain reporting but also physiological responses to painful stimulation (i.e., skin conductance responding). Interestingly, Jolliffe and Nicholas (2004) showed that awareness of the contingency between pain reporting and reinforcement was not predictive of differences in conditioning effects, suggesting that this learning process may occur independently of conscious awareness. Insights in these (interpersonal) conditioning processes have advanced understanding of chronic pain and have been successfully integrated in its treatment (den Hollander et al., 2010; Gatzounis, Schrooten, Crombez, & Vlaeyen, 2012).

The current experiment investigated how interpersonal interactions may affect subjective fatigue reporting and objective cognitive performance. More precisely, we aimed to bring fatigue reporting under operant control – through social reinforcement – while participants engaged in cognitive effort. Using a demanding working memory task to induce fatigue, subjective fatigue reports throughout this task were either reinforced by the experimenter (if higher than the previous report), or punished (if lower). We hypothesized that this conditioning procedure would result in higher fatigue reporting than in a control condition that only involved neutral feedback. We also investigated whether this effect would occur independently of conscious awareness. As a secondary question, we assessed whether our conditioning procedure also affected cognitive performance during the task. It is possible that not only subjective fatigue increases, but that objective performance also suffers as a result of interpersonal interactions that reinforce fatigue.

2. Method

2.1. Participants

Forty-four participants (40 women) with a mean age of 24.7 years (SD = 7.8) were recruited at Maastricht University, Netherlands. Participants could voluntarily sign up for this study using the university's online research participation system (Sona systems Ltd.) or by responding to an advertisement about this study in the university building. Although there are no previous studies on operant conditioning of fatigue, power analysis determined that this sample size would be sufficient to detect a small to medium-sized effect at 95% power, using $p < .05$. A small to medium effect size was assumed given that our operant conditioning manipulation was deliberately confined to subtle social reward or punishment, in order to mimic as closely as possible how these interactions may shape behavior in daily life situations independent of conscious awareness. Participants had to be 18 years or older to be included in the study. A good comprehension of Dutch language was required in order to participate. Participants were excluded if they reported to be currently suffering from (or diagnosed with) depression, chronic fatigue syndrome, dyslexia, or ADHD, as our fatigue induction requiring prolonged cognitive effort may have proven too burdensome for these individuals. The study was approved by the Ethical Review Committee Psychology and Neuroscience of Maastricht University. All participants gave their informed consent.

2.2. Working memory task

A dual 2-back task with a visual and auditory component was administered using Presentation® software, version 19.0, Neurobehavioral systems (California, USA). During this continuous working memory task, participants were required to actively monitor two sequences of stimuli (Fig. 1, panel a). Auditory stimuli were numbers ranging from 1 to 9 and were presented through headphones. Participants had to monitor whether the number they heard was identical to the number presented two numbers back (i.e., auditory target). Visual stimuli were presented simultaneously, which were black squares presented on the computer screen in one of eight possible places in a three-by-three grid (a fixation cross was presented in the center square of the grid). Similarly, participants had to monitor whether a square was presented in the same place as two presentations before (i.e., visual target). Stimuli were presented for 500 ms. The inter stimulus interval was set to 2500 ms. The task consisted of five blocks of five minutes (100 stimulus presentations per block), preceded by a short practice phase. Each block included eight visual targets, eight auditory targets, four dual targets with auditory and visual target presented simultaneously, and 80 stimulus presentations without a target presented.

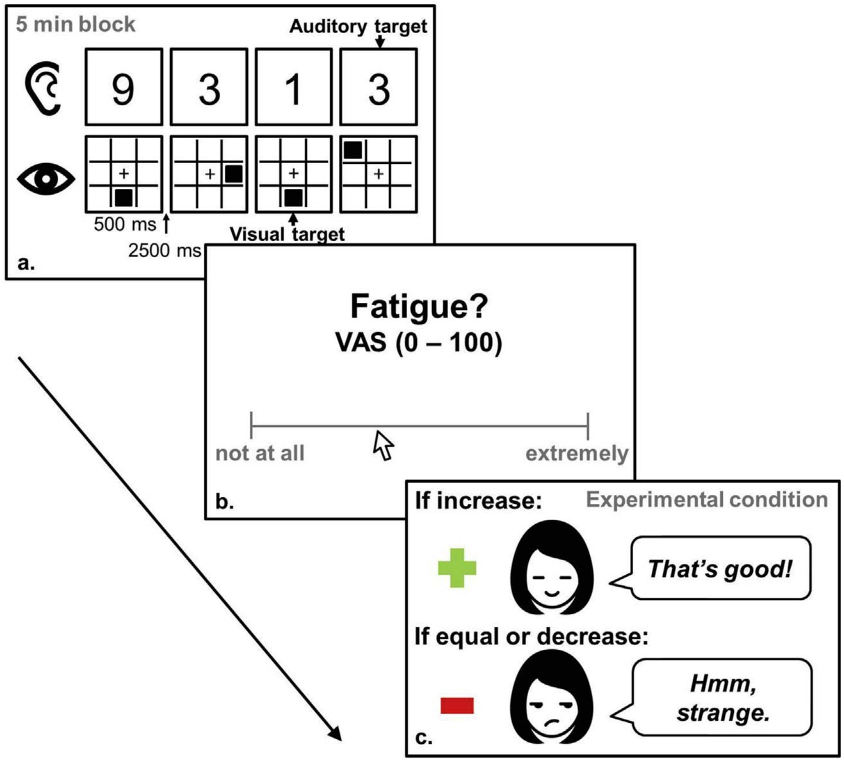

Fig. 1. Timeline for one of five identical blocks of the experimental procedure, consisting of (a) five minutes of the dual 2-back task; (b) subjective fatigue rating on a Visual Analogue Scale; (c) Reward or punishment by the experimenter. In the control condition, step (c) was replaced by neutral feedback.

Note: Pictograms of female faces created by Pham Thi Dieu Linh; Pictograms of ear and eye created by Jens Tärning; source of all pictograms: thenounproject.com; VAS = Visual Analogue Scale.

2.3. Subjective fatigue

After each block and before the first block (baseline), participants were requested to rate their subjective fatigue as experienced right now on a horizontal Visual Analogue Scale (VAS) ranging from "not at all" to "extremely" (Fig. 1, panel b). This rating was automatically visualized as a score ranging between 0 and 100 on a different computer screen in the same room; visible to the experimenter only.

2.4. Cognitive performance measures

Participants were instructed to hit the left mouse button when either a visual target or an auditory target – or both – was presented, or do nothing when no target was presented. For each of the five blocks, we recorded the number of targets hit (correct responses), and the number of correct rejections when no target was presented (correct non-responses).

2.5. Contingency awareness

At the end of the experiment, a two-staged interview was used to assess awareness of the response-reinforcement contingency. First, participants were asked whether they could identify the overall aim of the experiment. Second, participants were specifically asked if they could name a possible relationship between their fatigue responses throughout the task and the feedback of the experimenter. If participants were able to explain this relationship accurately in their own words, they were classified as 'contingency aware'.

2.6. Questionnaires

Two questionnaires were administered to assess pre-existing differences between conditions. The Fatigue Severity Scale (FSS) was used to assess fatigue and fatigue severity in daily life (Krupp, LaRocca, Muir-Nash, & Steinberg, 1989). The FSS consists of 9 statements (e.g., 'I am easily fatigued') rated on a 7-point Likert scale. Total score is calculated as mean score per item. Scores range from one to seven, with lower values indicating greater fatigue severity. We also assessed negative affect, or the disposition to experience negative mood states, because previous research has shown that high negative affectivity correlates positively with enhanced subjective symptom reports, including fatigue (e.g., Van Diest et al., 2005). Negative affect was assessed using the Dutch translation of the Positive and Negative Affect Schedule (PANAS) – trait version (Watson, Clark, & Tellegen, 1988), which consists of ten positive (e.g., 'enthusiastic') and ten negative (e.g., 'distressed', 'irritable', 'disappointed') adjectives that describe different mood states. Participants use a 5-point Likert scale to indicate to what extent they experience a certain mood state throughout daily life. The total negative affect score is obtained by adding the scores of the negative mood state items. Scores range from 10 to 50, with higher values indicating higher negative affectivity. Finally, we asked participants to rate how difficult they found the working memory task on a Likert scale ranging from 1 (not difficult at all) to 7 (extremely difficult).

2.7. Experimental procedure

Before the start of the experiment, participants were randomly assigned to the reinforcement condition or the control condition. All participants were informed that they would be participating in a study investigating how repetition of a cognitively demanding task affects working memory performance (cover story). They were also instructed that they would have to rate their subjectively experienced fatigue at regular intervals during the task. Finally, participants were informed that the experimenter would monitor their performance and responses on a different computer screen. After receiving verbal and written task instructions and a short practice phase, participants rated their currently experienced fatigue for the first time (baseline VAS fatigue rating). Subsequently, participants rated their currently experienced fatigue after each five minute block of the dual 2-back task. In the experimental condition, the (female) experimenter either verbally reinforced or punished these fatigue reports (Fig. 1, panel c). If a fatigue rating was higher than the previous rating, verbal praise/reward was given (i.e., "Good, we expected the task to become more fatiguing" after the first increase; and "That's it" or "Very good" thereafter). Verbal punishment/disapproval was given if a fatigue rating was lower than or equal to the previous rating (i.e., "Hmm strange, we expected the task to become more fatiguing"; and "Hmm, strange" thereafter). In the control condition, no reinforcement or punishment was given, and participants only received neutral feedback (i.e., "You will now continue with the next block"). After the dual 2-back task, experienced task difficulty was assessed and the questionnaires were administered. Finally, participants were interviewed about their awareness of the contingency between their fatigue ratings and the feedback they received. Afterwards, participants were fully debriefed about the aim of the experiment, and received monetary reward or course credits for their participation.

3. Results

3.1. Group statistics

The experimental (n = 22; mean age = 25.3; SD = 8.3) and control group (n = 22; mean age = 24.1; SD = 7.6) did not differ significantly in age, $t(42) = -0.51$, p = .611. There were also no differences in negative affect, $t(42) = 0.66$, p = .512, or fatigue severity in daily life, $t(42) = -0.71$, p = .480. Mean negative affect and fatigue severity scores (+SD) were respectively 16.7 (5.7) and 3.55 (0.9) in the experimental group, and17.7 (4.3) and 3.37 (0.8) in the control group. Mean subjective difficulty (+SD) of the dual 2-back task was 4.9 (1.5) for the reinforced group and 5.3 (1.2) for the control group, $t(42) = -1.02$, p = .314. With a range of 1–7, a mean score of 5.1 for the total sample indicates that the task was experienced as difficult.

3.2. Reinforcement effects

Subjective fatigue. The left panel of Fig. 2 depicts the mean increase in subjective fatigue ratings after each block relative to the baseline fatigue rating (before the first block). Visual inspection suggests that both conditions became more fatigued during the task, but more so in the experimental condition. Mean increases in fatigue ratings in the experimental condition were 18.50 points on the VAS scale after block 1, 28.27 (block 2), 41.05 (block3), 45.00 (block 4), and 50.32 (block 5). For the control condition this was 18.00 (block 1), 22.41 (block 2), 27.14 (block 3), 33.68 (block 4), and 36.55 (block 5). Both conditions showed a similar increase in fatigue ratings after the first block. From there, mean increases in fatigue ratings were higher in the experimental condition than in the control condition. This is in line with our predictions, as fatigue ratings in the experimental condition were reinforced or punished for the first time after the first block. To assess the effect of interpersonal reinforcement/punishment on fatigue reporting throughout the dual 2-back task, we performed a repeated measures ANOVA with reported Fatigue (difference from baseline) as dependent variable, with Block (1–5) as within-subjects factor, and Condition (Experimental; Control) as between-subjects factor. Greenhouse-Geisser corrections were applied, because Mauchly's sphericity test was significant, $\chi^2(9) = 87.10$, $p < .001$. Results showed a significant main effect of Fatigue Rating, $F(2,84) = 62.39$, $p < .001$, partial $\eta^2 = .598$. Planned comparisons revealed higher fatigue ratings after the last block than after the first block for the entire sample, indicating that fatigue ratings increased throughout the task, $F(1,42) = 95.08$, $p < .001$. There was no main effect of Condition, $F(1,42) = 2.23$, p = .143, partial $\eta^2 = .050$. Crucially, there was a significant Block × Condition interaction, $F(2,84) = 4.96$, p = .009, partial $\eta^2 = .106$, indicating that there was a differential pattern between conditions in fatigue ratings across task blocks. Planned comparisons revealed a larger difference in fatigue ratings between the last block and the first block in the experimental condition relative to the control condition, $F(1,42) = 6.60$, p = .014, partial $\eta^2 = .136$. These results indicate that fatigue ratings increased more in the condition that was socially reinforced/punished relative to the control condition. Finally, based on our contingency awareness interview, three out of 22 participants in the experimental condition were classified as "contingency aware". When these subjects were excluded from the analyses, the Block × Condition interaction remained significant and the effect size became even larger, $F(2,79) = 5.21$, p = .007, partial $\eta2$ = .118, indicating that operant conditioning effects occurred independently of conscious awareness.

Cognitive performance. The right panel of Fig. 2 depicts the number of correct rejections of non-target stimuli (correct non-responses) for each block during the dual 2-back task. Visual inspection suggests that the control condition became better at correctly rejecting non-targets during the task, whereas the experimental condition remained at the same level of performance. Mean number of correct rejections in the control condition was 72.32 in block 1, 75.32 (block 2), 76.68 (block3), 76.77 (block 4), and 76.95 (block 5). For the experimental condition this was 73.36 (block 1), 72.82 (block 2), 74.50 (block 3), 74.86 (block 4), and 74.23 (block 5). Repeated measures ANOVA with number of Correct Rejections as dependent variable, with Block (1–5) as within-subjects factor and Condition (Experimental; Control) as between-subjects factor revealed a main effect of Block, $F(2.6,107.1) = 7.9$, $p < .001$, partial $\eta2$ = .158. There was no main effect of Condition, $F(1,42) = 0.79$, p = .380, partial $\eta2$ = .018, but there was a Block × Condition interaction, $F(4,168) = 2.82$, p = .027, partial $\eta2$ = .063. However, only a trend remained after applying Greinhouse-Geisser correction, $F(2.6,107.1) = 2.82$, p = .051, partial $\eta2$ = .063 (Mauchly's sphericity test: $\chi^2(9) = 37.37$, $p < .001$). An independent samples t-test, with the difference in number of correct

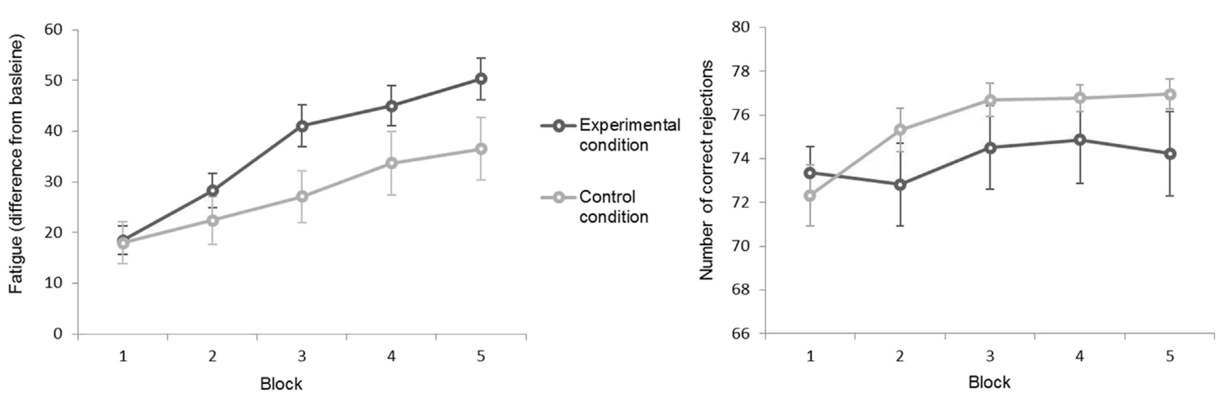

Fig. 2. Left panel: Mean fatigue ratings (difference from baseline) for both conditions after each of five blocks of the dual 2-back task for both conditions; Right panel: Mean number of correct rejections in each condition during five blocks of the dual 2-back task; Error bars represent ± 1 SE.

rejections between the first and the last block as the dependent variable, did reveal a smaller increase in performance in the experimental condition compared with the control condition, $t(42) = -2.21$, $p = .033$. In fact, the number of correct rejections was significantly higher in the last block than in the first block for the control condition, $t(21) = 4.25$, $p < .001$ (mean difference = 4.64), but not for the experimental condition, $t(21) = 0.66$, $p = .519$ (mean difference = 0.86). These results suggest that our operant conditioning procedure also led to differences in objective cognitive performance. Finally, the same repeated measures ANOVA with number of Hits (correct responses) for each block (Block 1–5) as within-subjects factor revealed no significant effects (results not shown).

4. Discussion

This is the first experimental investigation of how interpersonal operant conditioning can shape subjective fatigue reporting. Our manipulation involving reinforcement of increases in fatigue reporting and disapproval (punishment) of decreases in fatigue reporting led to higher subjectively reported fatigue relative to a control condition that was not conditioned while executing the same cognitive task. These results indicate that reporting fatigue may become controlled by its consequences (*i.c.*, social reward/disapproval), and not exclusively by preceding events such as (mental) effort or illness. Interpersonal interactions that reinforce fatigue reporting may perpetuate and strengthen this behavior in the future. Although future research in clinical populations is warranted, these findings suggest that interpersonal operant conditioning may play a role in fatigue and fatigue-related behavior becoming a chronic problem. A similar conditioning experiment with positive and negative feedback to pain reports showed that subjective pain reporting of both chronic back pain patients and healthy control subjects can be brought under operant control. Interestingly, when positive or negative feedback was no longer given to pain reports, healthy participants showed fast extinction, whereas the chronic back pain patients maintained their elevated pain ratings. This may suggest that patients were more easily influenced by operant conditioning than healthy controls, pointing to a role of conditioning processes in the maintenance of chronic pain (Flor, Knost, & Birbaumer, 2002). In the context of fatigue, this implies that individuals who are more easily influenced by interpersonal operant conditioning processes may be more prone to develop or maintain chronic fatigue complaints. Susceptibility to operant conditioning by the social environment – and individual differences therein – may help explain the trajectory towards chronic fatigue across diagnostic categories, which is still poorly understood.

Moreover, interpersonal operant conditioning occurred independently of conscious awareness, suggesting that these learning processes may happen in daily life without the person whose behavior is reinforced realizing it. This also underlines the complexity of disentangling the subjective fatigue experience from communicating this experience. Similar to pain, hunger, or anxiety for instance, the subjective feeling of fatigue is the primary marker of the state 'fatigue' (Hockey, 2013). To the extent that there are no motives for misrepresentation (e.g., social desirability; over-reporting in clinical assessment), subjective fatigue reports are a reliable source to assess that state; and may be the only valid way to access it. In this experiment, most participants were unaware of reinforcement contingencies, ruling out social desirability as an alternative explanation. Hence, it is plausible to assume that the differences between conditions in fatigue *reporting* reflected differences in subjective fatigue *experience* in this experiment.

Our results are in line with cross-sectional evidence in patients with chronic fatigue syndrome showing a relationship between solicitous behavior from significant others and higher levels of fatigue severity (Band et al., 2015). Our findings add to this literature by suggesting a causal role of interpersonal operant conditioning in elevated fatigue reporting. Moreover, the observation that this process may escape conscious awareness calls for heightened awareness of these social influences on behavior in treatment of chronic fatigue. First, therapists should be aware that interaction patterns in the social environment of the person being treated can maintain and strengthen fatigue complaints. For instance, a significant other of an individual suffering from chronic fatigue who – with best intentions – is solicitous and supportive to fatigue complaints, may instead be encouraged to start reinforcing alternative behaviors, such as taking on activities in spite of fatigue. Second, therapists should take into account their own influence in the shaping of fatigue reporting. Indeed, our results point to the importance of finding a delicate balance in treatment, where sufficient empathy is shown while avoiding adverse effects by reinforcing and maintaining fatigue complaints.

It is intriguing that our manipulation also affected objective performance; with the experimental condition correctly rejecting fewer non-target stimuli than the control condition. On the one hand, this finding points to the strength of our manipulation, in that it not only impacted subjective fatigue measures, but also cognitive performance. On the other hand, it raises new questions about the potential underlying mechanisms between operant conditioning of fatigue and poorer cognitive performance. In his motivational theory of fatigue, Hockey (2013) has proposed to consider fatigue as an emotion that includes a tendency to change behavior. More precisely, fatigue interrupts ongoing behavior to allow alternative behaviors competing for motivational control. In our experiment, operant conditioning may have led to changes in motivation that negatively impacted performance on the working memory task. Future research in more ecologically valid settings should investigate whether interpersonal operant conditioning also affects performance in everyday tasks that require sustained cognitive effort, and whether this effect can be attributed to decreases in motivation.

Further, although we have no theoretical arguments why interpersonal operant conditioning should affect physical and cognitive fatigue (reporting) differently, future studies could assess whether our conclusions apply to fatigue induced by sustained physical effort. It is also of note that fatigue in individuals with chronic fatigue symptoms is not always related to prior (cognitive or physical) effort. Rather, fatigue may be present constantly throughout the day or immediately upon waking. In that respect, fatigue induced by a cognitive task may not cover the total experiential variance in fatigue in the daily lives of individuals with chronic fatigue symptoms. Hence, the generalizability of our findings may be restricted by the extent to which the social environment responds differently to fatigue reporting after an effortful task as opposed to fatigue reporting in the absence of prior effort.

Finally, our crucial manipulation may not only have operantly conditioned fatigue reporting, but may have also conveyed expectancies about what participants' experiences should be. Indeed, after the first increase or decrease in fatigue reporting during the cognitive task, the experimenter not only expressed approval or disapproval, but also conveyed an expectancy (e.g., "Good, we expected the task to become more fatiguing"). The experimenter used this expression once in order to make the manipulation more powerful, and we would argue that this may in fact accurately capture the behavior from significant others in daily life. That is, solicitous responding by significant others may also convey expectancies about what the fatigue experience should be in the person whose behavior is being reinforced (e.g. "I bet you had a rough day"; or "I can imagine you feel exhausted right now"). As such, interpersonal interactions in daily life may strengthen fatigue complaints by reinforcing fatigue reporting on the one hand, as well as by inducing expectancies about the fatigue experience on the other hand. Because we did not measure expectancies about fatigue, our experiment does not allow disentangling these two processes. However, the choice to not measure fatigue expectancies was made deliberately. The main reason for this was that it would have become very difficult for participants to learn which behavior was being reinforced. If we would have asked participants to rate not only their currently experienced fatigue after each block but also their fatigue expectancy, it may be unclear to which of these two responses feedback is given by the experimenter. A second reason is that the inclusion of an extra question about fatigue expectancy may have revealed too much information about our crucial manipulation. Future studies could investigate to what extent solicitous responding by significant others inadvertently induces negative expectancies about the fatigue experience, which could give rise to nocebo effects.

Limitations include the overrepresentation of female participants (see on gender differences in symptom reporting: Van Diest et al., 2005) and the relatively small sample size. Further, we did not measure motivational change. Operant conditioning may also influence motivational components of fatigue (e.g., urge to stop) and related avoidance/escape behavior. This experiment only included a condition where fatigue reports were conditioned upwards (i.e., increases were rewarded, decreases were punished), relative to a neutral feedback control group. Future research could investigate whether fatigue reports can also be conditioned downwards (i.e., by rewarding decreases and punishing increases), and whether cognitive performance would also improve accordingly. Such result would have direct implications for the treatment of fatigue. Finally, because the control condition only involved neutral feedback, it is possible that the experimental and control group also differed in their emotional response to the manipulation. We did not measure the impact of our manipulation on mood or emotional state in this study. Future research could assess whether operant conditioning of fatigue reports also evokes an emotional response which may further influence fatigue and fatigue-related behavior (e.g., avoidance).

In conclusion, we showed that it is possible to bring subjective fatigue reporting under operant control through social reinforcement and punishment of fatigue reports. Moreover, our manipulation also negatively impacted objective cognitive performance. Finally, the shaping of subjective fatigue reporting occurred independently of conscious awareness. This is all the more intriguing, as the shaping of behavior by the social environment in daily life may be subtle, occurring in multiple interactions over longer time periods. This may eventually install or perpetuate a pattern characterized by chronic fatigue complaints and disability. Because learning the relation between our actions and their outcomes is such a fundamental capacity to human (associative) learning, these results suggest that operant conditioning may act as a trans-diagnostic process maintaining fatigue in a variety of disorders.

References

Band, R., Wearden, A., & Barrowclough, C. (2015). Patient outcomes in association with significant other responses to chronic fatigue syndrome: A systematic review of the literature. *Clinical Psychology: Science and Practice, 22*, 29–46.

Brown, R. J. (2004). Psychological mechanisms of medically unexplained symptoms: An integrative conceptual model. *Psychological Bulletin, 130*, 793–812. http://dx.doi.org/10.1037/0033-2909.130.5.793.

Chaudhuri, A., & Behan, P. O. (2004). Fatigue in neurological disorders. *The Lancet (North American Edition), 363*, 978–988. http://dx.doi.org/10.1016/S0140-6736(04)15794-2.

Cumming, T. B., Packer, M., Kramer, S. F., & English, C. (2016). The prevalence of fatigue afterstroke: A systematic review and meta-analysis. *International Journal of Stroke, 11*, 968–977. http://dx.doi.org/10.1177/1747493016669861.

Domjan, M. (2005). *The essentials of conditioning and learning* (3rd ed.). California, USA: Thomson Wadsworth.

Flor, H., Knost, B., & Birbaumer, N. (2002). The role of operant conditioning in chronic pain: An experimental investigation. *Pain, 95*, 111–118. http://dx.doi.org/10.1016/S0304-3959(01)00385-2.

Fordyce, W. E. (1976). *Behavioral methods for chronic pain and illness.* St. Louis: Mosby.

Gatzounis, R., Schrooten, M. G., Crombez, G., & Vlaeyen, J. W. (2012). Operant learning theory in pain and chronic pain rehabilitation. *Current Pain and Headache Reports, 16*, 117–126. http://dx.doi.org/10.1007/s11916-012-0247-1.

Heesen, C., Nawrath, L., Reich, C., Bauer, N., Schulz, K. H., & Gold, S. M. (2006). Fatigue in multiple sclerosis: An example of cytokine mediated sickness behaviour? *Journal of Neurology, Neurosurgery & Psychiatry, 77*, 34–39. http://dx.doi.org/10.1136/jnnp.2005.065805.

Hockey, R. (2013). *The psychology of fatigue.* New York, USA: Cambridge University Press.

den Hollander, M., de Jong, J. R., Volders, S., Goossens, M. E., Smeets, R. J., et al. (2010). Fear reduction in patients with chronic pain: A learning theory perspective. *Expert Review of Neurotherapeutics, 10*, 1733–1745. http://dx.doi.org/10.1586/ern.10.115.

Jason, L. A., Jordan, K. M., Richman, J. A., Rademaker, A. W., Huang, C.-F., McCready, W., et al. (1999). A community-based study of prolonged fatigue and chronic fatigue. *Journal of Health Psychology, 4*, 9–26. http://dx.doi.org/10.1177/135910539900400103.

Jolliffe, C. D., & Nicholas, M. K. (2004). Verbally reinforcing pain reports: An experimental test of the operant model of chronic pain. *Pain, 107*, 167–175. http://dx.doi.org/10.1016/j.pain.2003.10.015.

Kluger, B. M., Krupp, L. B., & Enoka, R. M. (2013). Fatigue and fatigability in neurologic illnesses: Proposal for a unified taxonomy. *Neurology, 80*, 409–416. http://dx.doi.org/10.1212/WNL.0b013e31827f07be.

Knoop, H., Prins, J. B., Moss-Morris, R., & Bleijenberg, G. (2010). The central role of cognitive processes in the perpetuation of chronic fatigue syndrome. *Journal of Psychosomatic Research, 68*, 489–494. http://dx.doi.org/10.1016/j.jpsychores.2010.01.022.

Krupp, L. B., LaRocca, N. G., Muir-Nash, J., & Steinberg, A. D. (1989). The fatigue severity scale: Application to patients with multiple sclerosis and systemic lupus erythematosus. *Archives of Neurology, 46*, 1121–1123. http://dx.doi.org/10.1001/archneur.1989.00520460115022.

Lenaert, B., Boddez, Y., Vlaeyen, J. W., & van Heugten, C. M. (2018). Learning to feel tired: A learning trajectory towards chronic fatigue. *Behaviour Research and Therapy, 100*, 54–66.

van't Leven, M., Zielhuis, G. A., van der Meer, J. W., Verbeek, A. L., & Bleijenberg, G. (2009). Fatigue and chronic fatigue syndrome-like complaints in the general population. *The European Journal of Public Health, 20*, 251–257. http://dx.doi.org/10.1093/eurpub/ckp113.

Linton, S. J., & Götestam, K. G. (1985). Controlling pain reports through operant conditioning: A laboratory demonstration. *Perceptual & Motor Skills, 60*, 427–437. http://dx.doi.org/10.2466/pms.1985.60.2.427.

Loge, J. H., Ekeberg, Ø., & Kaasa, S. (1998). Fatigue in the general Norwegian population: Normative data and associations. *Journal of Psychosomatic Research, 45*, 53–65. http://dx.doi.org/10.1016/S0022-3999(97)00291-2.

Lousberg, R., Groenman, N. H., Schmidt, A. J., & Gielen, A. A. (1996). Operant conditioning of the pain experience. *Perceptual & Motor Skills, 83*, 883–900. http://dx.doi.org/10.2466/pms.1996.83.3.883.

Lukkahatai, N., & Saligan, L. N. (2013). Association of catastrophizing and fatigue: A systematic review. *Journal of Psychosomatic Research, 74*, 100–109. http://dx.doi.org/10.1016/j.jpsychores.2012.11.006.

Pardini, M., Bonzano, L., Mancardi, G. L., & Roccatagliata, L. (2010). Frontal networks play a role in fatigue perception in multiple sclerosis. *Behavioral Neuroscience, 124*, 329. http://dx.doi.org/10.1037/a0019585.

Rief, W., & Broadbent, E. (2007). Explaining medically unexplained symptoms-models and mechanisms. *Clinical Psychology Review, 27*, 821–841. http://dx.doi.org/10.1016/j.cpr.2007.07.005.

Rogers, D. C., Dittner, A. J., Rimes, K. A., & Chalder, T. (2017). Fatigue in an adult attention deficit hyperactivity disorder poulation: A trans-diagnostic approach. *British Journal of Clinical Psychology, 56*, 33–52. http://dx.doi.org/10.1111/bjc.12119.

Romano, J. M., Jensen, M. P., Schmaling, K. B., Hops, H., & Buchwald, D. S. (2009). Illness behaviors in patients with unexplained chronic fatigue are associated with significant other responses. *Journal of Behavioral Medicine, 32*, 558.

Schmaling, K. B., Smith, W. R., & Buchwald, D. S. (2000). Significant other responses are associated with fatigue and functional status among patients with chronic fatigue syndrome. *Psychosomatic Medicine, 62*, 444–450.

Stebbings, S., & Treharne, G. J. (2010). Fatigue in rheumatic disease: An overview. *International journalof clinical rheumatology, 5*, 487–502. http://dx.doi.org/10.2217/IJR.10.30.

Van Diest, I., De Peuter, S., Eertmans, A., Bogaerts, K., Victoir, A., & Van den Bergh, O. (2005). Negative affectivity and enhanced symptom reports: Differentiating between symptoms in men and women. *Social Science & Medicine, 61*, 1835–1845. http://dx.doi.org/10.1016/j.socscimed.2005.03.031.

Van den Bergh, O., Witthöft, M., Petersen, S., & Brown, R. J. (2017). Symptoms and the body: Taking the inferential leap. *Neuroscience & Biobehavioral Reviews, 74*, 185–203. http://dx.doi.org/10.1016/j.neubiorev.2017.01.015.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070. http://dx.doi.org/10.1037/0022-3514.54.6.1063.

Wyller, V. B., Eriksen, H. R., & Malterud, K. (2009). Can sustained arousal explain the chronic fatigue syndrome? *Behavioral and Brain Functions, 5*, 10. http://dx.doi.org/10.1186/1744-9081-5-10.