



‘No Man is an Island’: Effects of social seclusion on social dream content and REM sleep

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Based on the Social Simulation Theory of dreaming (SST), we studied the effects of voluntary social seclusion on dream content and sleep structure. Specifically, we studied the *Compensation Hypothesis*, which predicts social dream contents to increase during social seclusion, the *Sociality Bias* – a ratio between dream and wake interactions – and the *Strengthening Hypothesis*, which predicts an increase in familiar dream characters during seclusion. Additionally, we assessed changes in the proportion of REM sleep. Sleep data and dream reports from 18 participants were collected preceding ($n = 94$), during ($n = 90$) and after ($n = 119$) a seclusion retreat. Data were analysed using linear mixed-effects models. We failed to support the Compensation Hypothesis, with dreams evidencing fewer social interactions during seclusion. The Strengthening Hypothesis was supported, with more familiar characters present in seclusion dreams. Dream social interactions maintained the Sociality Bias even under seclusion. Additionally, REM sleep increased during seclusion, coinciding with previous literature and tentatively supporting the proposed attachment function for social REM sleep.

A third of our lives is spent asleep, predominantly immersed in internally generated experiences – dreams. While loneliness has been found to affect the social contents of daydreams (Mar, Mason, & Litvack, 2012; Poerio & Smallwood, 2016; Poerio, Totterdell, Emerson, & Miles, 2016), the effects of changes in social environment on dreams remain rarely studied. What happens to our social dream content when our social life is upended in the waking world, given dreams are predominantly social? Due to the COVID-19 pandemic, this question has recently become relevant. The global mitigation efforts of the SARS-CoV-2 virus have required either voluntary self-isolation, mandated quarantine, or in the very least

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The title of this article is derived from the modern translation of a poem by John Donne (1624). While it picks up the essential theme of the paper, the authors note the archaic nomenclature ‘man’ does not reflect the current usage nor the characteristics of our sample.

‘No man is an Iland, intire of it selfe; every man is a peece of the Continent, a part of the Maine’ (Donne, 1624/1923, p. 98).

changed our normal social behaviours and turned previously non-conscious social behaviours into intricate problems of social coordination. The pandemic has also affected the contents of dreams (see Barrett, 2020; Mota et al., 2020; Pesonen et al., 2020; Scarpelli et al., 2021; Wang, Zemmelman, Hong, Feng, & Shen, 2021). Given the negative effects caused by the pandemic itself the effects of mere social isolation or exclusion¹ on dreams remain difficult to unpack. In this study, we aim to address this question by modulating the social environment while controlling for possible other factors, such as stress or uncertainty.

Dreams frequently include social perception and interaction, with on average 2–4 human characters per dream (Nielsen & Lara-Carrasco, 2007). Only in 4.3% of reports the dream self is alone (Domhoff & Schneider, 2018). Research comparing dreams with wake reports has shown dreams to contain more social situations than corresponding waking life (McNamara, McLaren, Smith, Brown, & Stickgold, 2005; Tuominen, Stenberg, Revonsuo, & Valli, 2019). Furthermore, our ability to consider the internal states of others – mindreading – is retained during dreaming. This ability has been considered essential in evolutionary terms, allowing us to coordinate behaviour, cooperate over time and with unfamiliar individuals and to predict the intentions, actions, and emotional responses of others. Kahn and Hobson (2005) found a majority of dreams to contain instances of mindreading. This finding is very interesting, given the other dream characters are generated by our own sleeping brain and we as their procreator should be intimately familiar with them and the behaviour of dream characters should thus be transparent. Mindreading has therefore been considered a prime candidate to reflect the predictions of the *Practise and Preparation hypothesis* of the Social Simulation Theory (SST) of dreaming, which suggests dreams carry a social function by enabling the practice of relevant social skills during dreams (Revonsuo, Tuominen, & Valli, 2016a). McNamara, McLaren, and Durso (2007) suggested that mindreading in dreams helps attain social goals in waking life, whereas Kahn and Hobson (2005) suggest that it rehearses our ability to evaluate what kind of social behaviours are appropriate in different situations. Mindreading has been found to be present in dreams especially when the dream self has acted aggressively towards a known dream character (McNamara et al., 2007). The presentation of novel recombinations of simulated social events in a nightly recurring virtual environment of dreams – free from both risks and costs similar situations would have in waking life – is considered biologically adaptive in the SST.

Who, then, are the characters we dream about and practice such situations with? Research indicates a dynamic for social dream contents between waking and dreaming social worlds. Evidence for such an interplay has, for example, included preparatory appearances of classmates in dreams before a scheduled class reunion pointing towards not only a reactive, but a predictive social function. Classmates, forming a key social structure during adolescence continues to inhabit about 5% of our dreams long after our actual interaction with them has ceased, to peak at nearly 15% at times of reunion (Schredl, 2012a, 2012b). Similarly, relationship status seems to have an impact on dream content, with those in stable relationships dreaming more often of their current partner (Schredl & Hofmann, 2003; Schredl, 2011) but also in the appearance of former romantic partners in dreams (Schredl, 2018). The actual gender distribution people engage with also seems to carry an effect on the gender distribution in dreams (Paul & Schredl, 2012). A causal effect

¹ While isolation and exclusion are synonyms, isolation is more often used in an involuntary and seclusion in a voluntary context. Furthermore, loneliness is also often termed perceived social isolation highlighting the role of subjectivity. Thus, one can be surrounded by people yet perceive oneself as isolated (Cacioppo & Hawkley, 2009). As such these three conditions also have different psychological consequences.

of dream content on subsequent social behaviour was uncovered by Selterman and colleagues (Selterman, Apetroaia, Riela, & Aron, 2014). Dreams that contained, for example, jealousy or infidelity were associated with increased conflict and less intimate feelings the following day. Additionally, the role of attachment seems to affect social dream content. For example, those with anxious or avoidant attachment styles reported more stress, conflict, and negative emotions when dreaming about their romantic partners (Selterman & Drigotas, 2009). Similarly, in people suffering from complicated grief disorder the loss of an attachment figure has been reported to decrease the amount of family members in dreams (Germain et al., 2013). Friends are reported to inhabit approximately 20% of our dreams (Roll & Millen, 1979), and a single-subject dream series study by Schredl (2012a, 2012b) discovered the presence of old school mates to maintain at 5% of dream characters.

The Social Simulation Theory of dreaming (SST) proposes a social function for dream content (Revonsuo, Tuominen, & Valli, 2016a). SST suggests contents of dreams to serve as simulations for real-life social events. The present study took this theory as its starting point with aim of explicitly testing hypotheses derived from it. Two original SST hypotheses are of interest here: The *Sociality Bias* and the *Strengthening Hypothesis*. Briefly, the *Sociality Bias* argues that for dreams to carry out a specific social function, they should be selectively biased towards social content compared to corresponding waking life. The *Strengthening Hypothesis* predicts dreams to especially simulate non-negative interactions with close relationships to strengthen or maintain social bonds, aiding social inclusion and cohesion. These have been amended with the *Compensation Hypothesis*, which considers dreams to aid in social belonging when social life is diminished (Tuominen, Stenberg, et al., 2019). SST mimics the content selection mechanism introduced in the *Threat Simulation Theory* of dreaming (TST; Revonsuo, 2000). In TST, threatening environments cause the dream generation system to increase the simulation of threatening events (Valli et al., 2005). SST proposes a similar mechanism for triggering social dream content to increase the likelihood to remain or be reincorporated into a social group. This development borrows from Leary et al. (1995) sociometer theory, where the level of group inclusion is internally monitored in the form of self-worth (Leary et al. 1998). When exclusion is experienced, a social monitoring system (Gardner, Pickett, & Brewer, 2000) begins to guide social information processing (Pickett, Gardner, & Knowles, 2004). For dream content selection, a mechanism like the sociometer (Gardner, Pickett, & Knowles, 2005) tracks our belongingness into a group, and when threat of exclusion is imminent, should promote social dream contents that aid in either reinclusion or inclusion in another group (Revonsuo et al., 2016a). The social psychology literature suggests that whether the response is prosocial or hostile depends on the level of control the person perceives to have on the social judgement (Warburton, Williams, & Cairns, 2006). Given such psychological variables would seem to bear on the responses and – according to the SST – on the consequent social dream content, there have surprisingly been no studies on possible moderating or mediating effects of such factors as belongingness or mentalizing capacity, and only a few on the effects of depression (Langs, 1966). Given that all these factors affect our social cognition, a more careful control of such individual differences would be called for. By developing a more thorough understanding on the interplay between psychological variables and social dream content, we could develop theories with more accurate predictions. Here, we assume these features to be related to the sensitivity to changes in the immediate social environment. While belongingness is considered a basic human motive towards attachment and social bonds, its level still varies between persons and could explain

social experiences and behaviours (Baumeister & Leary, 1995). For example, in a sample of persons with borderline personality disorder need to belong mediated rejection sensitivity (Sato, Fonagy, & Luyten, 2020). Similarly, the ability to mentalize, that is, to consider other as intentional beings with unique mental states is considered essential in daily social functioning and affects our inferences of other people's behaviour and our relation to them (Frith & Frith, 2003). Given the previously noted abundance of mental state inference in dreams, this ability is likely a contributing factor to individual differences in internally generated social dream worlds.

The *Compensation Hypothesis* makes the risky prediction that a decrease in social interactions in waking life would not be mirrored by a similar decrease in dreams but could even lead to an increase in social events. Given that the proposed threat of exclusion can be both concrete or perceived, we can further subdivide this hypothesis into two: First, on the one hand, *the regular form of the Compensation Hypothesis* would consider not only the actual number of wake social interactions and their participants, but also the fears and perceived threats experienced by the person. For example, one could be included in an actively meeting group, yet perceive a threat of exclusion. Such experiences can be experimentally induced via measures such as Cyberball – a simple collaborative ball-throwing game designed to induce feelings of rejection by excluding the participant from other players (Williams & Jarvis, 2006) – yet they can be argued to lack the required ecological validity. On the other hand, an ecologically valid research setting of such a situation would carry large ethical problems. Second, *the strong form of the Compensation Hypothesis* would state this process to be more direct, affected already by mere social isolation or exclusion without the threat of actual exclusion.

Additionally, the *Strengthening Hypothesis* makes more specific predictions on the type of dream characters. A previous investigation into whether dreams especially simulate interactions with close others found no support for the *Strengthening Hypothesis*, calling for a replication and a reassessment of the hypothesis (Tuominen, Revonsuo, & Valli, 2019). The *Strengthening Hypothesis* predicts seclusion to alter the relative proportions of different types of characters appearing in dreams: When belongingness to a group is threatened, an increase in non-negative interactions with close others in dreams should be observed. Thus, the dreams would aid the individual in reconnecting with the group and avoiding exclusion (Tuominen, Revonsuo, et al., 2019; Tuominen, Stenberg, et al., 2019).

Previous research indicates that dream contents reflect changes in waking relationships. In an analysis of a dream series during and after imprisonment, Mérei (1994) tracked the correspondence between social relationships in dreams and waking life. Close relationships persisted in dreams throughout the three-year incarceration period, whereas other relationships slowly faded. Following release, the prison inmates continued to manifest in his dreams. The effects of social isolation on dream contents have also been studied in two unpublished doctoral dissertations. Wood (1962) found one-day social isolation to increase REM sleep and number of characters in dreams. In contrast, Dallett (1973) found no support for such compensation using a group-level ANOVA. Whereas Dallett controlled for report length Wood did not. Indeed, when Dallett analysed the data without controlling for length, an effect for increased social interactions in dreams was uncovered. However, the period of isolation in Dallett's study was only eight hours, after which the participants returned home for dream reporting.

Although our study is specifically designed to test the SST as it is a theory of social contents in dreams, several other dream theories may be compared to or contrasted with SST. Continuity Hypotheses² are among the most commonly utilized to investigate social dream contents. They maintain that dreaming serves no separate biological function, but is merely continuous with wake processing: either with actual wake events (Incorporation Continuity Hypothesis; ICH; Schredl & Hofmann, 2003) or with the persons current concerns more broadly (Cognitive Continuity Hypothesis; CCH; Domhoff, 2017). Of these, ICH seems to fair badly with the view that dream contents are selectively biased to include, for example, more social or threatening contents compared to corresponding wake report contents. With regard to the compensation hypothesis of the SST, ICH should predict a corresponding decrease in dream social contents when social contact is minimized. With CCH, the topic is slightly more complex. It would be reasonable to suggest that, for example, exclusion from a group would also cause concern in the waking thoughts of the participant. Overall, the problem with CCH is a methodological one: How to design a study that tracks current concerns of the participants clearly enough to be correlated with similar dream report concerns (the problem of specificity) without simultaneously functioning as a priming task to the dream report study (the problem of demand characteristics)? These problems were partially addressed in a study that assessed the continuity of both the current concerns of the dreamer and exact waking replay of wake episodes in a meticulous two-week study by Fosse, Fosse, Hobson, and Stickgold (2003). The subjects kept a dream diary together with a log of their concerns and activities during the fortnight. Of the reports, 65% were assessed to retain some aspect of any wake experiences (mostly characters, emotions and themes), whereas only 1.7% plausibly replicated an episode as such. This is in contrast with an earlier study by Dement, Kahn, and Roffwarg (1965) with a less stringent matching criteria, which found 12% of the dreams to replay wake events, and most of which incorporated the laboratory setting during the first measurement session. In this study, we were more straightforwardly interested in testing the SST predictions concerned with the effects of concrete environmental alterations. However, as with TST, SST is not necessarily mutually exclusive with either CCH or ERT as they seem to target slightly different theoretical levels. It does, however, differ between some of the background assumptions related to the function of dreams and the emphasis on content type. Whereas TST and SST both posit a biological function for dreaming, CCH and ERT propose a psychological function, more akin to a psychotherapeutic function of processing present concerns.

Additionally, some theoretical suggestions and empirical findings bear on the relationship between rapid eye movement (REM) sleep and social relationships. While dreaming takes place extensively in REM sleep, it also occurs during non-REM sleep stages (NREM; Fosse, Stickgold, & Hobson, 2001). There are a wide variety of theories for the function of REM sleep, ranging beyond the scope of this article (for a review, see Peever & Fuller, 2017). While the exact nature and function of REM sleep for social relationships remains unresolved (Beattie, Kyle, Espie, & Biello, 2015), there have been some

² There is an ongoing debate around the use of the term Continuity Hypothesis (see (Domhoff, 2011, 2017; Schredl, 2012a, 2017). For clarity, we follow (Tuominen et al., 2019) and differentiate between a version proposed by Schredl and Hofmann (2003) the Incorporation Continuity Hypothesis (ICH), as its central claim is that waking events and activities are incorporated into dreams. Alternatively, Domhoff's (1996, 2003) version is referred to as the Cognitive Continuity Hypothesis (CCH), as it maintains that dreams are modulated by waking personal interests, conceptions and concerns. Schredl's more developed mathematical model (Schredl, 2003) would in this classification fall closer to ICH, yet it provides a more nuanced view as individual factors and experience-related factors are considered to modulate the dream contents. Both can be seen as developments from the original conceptualization of Hall & Nordby (1972).

theoretical attempts to address this connection. Most directly, McNamara (1996) proposes REM sleep as a social bonding mechanism, aiding in forming and strengthening attachment relationships. Additionally, McNamara and colleagues (McNamara et al., 2005) found REM sleep to be associated with aggressive social dream content compared to the prosocial content of NREM sleep. However, Tuominen, Revonsuo, et al. (2019) and Tuominen, Stenberg, et al. (2019) failed to replicate this finding when controlling for report length and found no differences in social content between early and late sleep stages. Similarly, in a later study McNamara et al. (2007) found that in NREM sleep the Self was never an initiator of aggression, whereas in REM sleep this was the case over half of the time (for a review of similar findings, see McNamara et al., 2010). Perogamvros et al. (2017) also found an increased social focus in REM sleep in a study comparing wakefulness, REM, and NREM sleep.

In this study, we focused on testing specific hypotheses of SST: a strong version of the *Compensation Hypothesis*³ and studied the effects of social seclusion on dream content and sleep structure. Our hypotheses were as follows: (1) social seclusion increases social interaction simulations in dreams (*Compensation Hypothesis*); (2) mentalizing, belongingness and depression influence sensitivity to the changes in social environment as measured by the wake/dream sociality ratio (*Sociality Bias*); (3) social seclusion leads to increased simulation of close relationships (*Strengthening Hypothesis*); and (4) REM sleep increases following seclusion.

Method

Procedure and materials

Participants and study procedure

The study took place in two three-week periods with nine participants each in a similar setting. Participants were recruited through university mailing lists and reached students, staff, and alumni. The selection process included an online *Pittsburgh Sleep Quality Index* (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) and general questions about interest in dreams, filled by 27 participants. Participants were approached based on their gender (matched) and PSQI scores. Existing neurological or psychiatric diagnoses were treated as exclusion criteria. Altogether, 20 participants were selected to take part in the study. The sample size was limited by feasibility and resource limitations. For this reason, we only assessed main effects to avoid overfitting. Additionally, two participants cancelled on the mornings of the seclusion week, leaving the total sample size at 18 (13 women, $M_{\text{age}} = 30.17$ $SD_{\text{age}} = 8.29$, range = 19–54).

Questionnaires related to well-being and social behaviour were collected both before and after the study period. The participants reported dreams from three nights preceding the experimental condition, with one non-reported night between these and the experimental sessions. These reports were used to ensure that participants can follow the dream reporting procedure and were included in the study pre-seclusion data. Questionnaires, and dream and mindwandering reports, were collected via Webropol-based online questionnaires (www.webropol-surveys.com). The participants were given an information sheet on how to accurately report their dreams (a translated, slightly

³ We tested the strong version of the compensation hypothesis by controlling the confounding effects from negative emotions caused by seclusion and attempted to isolate the specific effect of diminished real-life social interactions. Thus, we strove to make the social seclusion retreat as pleasant and free of external stress as possible.

modified version of the reporting instructions can be found at <https://sites.utu.fi/mind/en/reporting-instructions/>). These instructions were also provided to the participants in a printed form for the seclusion period. During the reporting, the online platform prompted the participants to report their dream as accurately and truthfully as possible in the given answer box, one dream at a time. For each dream report, they also indicated the approximate number of social interactions they had experienced during the preceding day and assessed the emotional tone of the dream (emotions in dreams form another study line and will be published elsewhere).

On the Monday of the seclusion retreat, the participants were shipped to a university research facility on the remote island of Seili in the Turku archipelago. The participants were given single rooms for the four nights of the study. Two researchers were also present on the island for the whole period to run the practicalities of the experiment and function as emergency contacts. As the study took place in late September (group 1) and early October (group 2), there were only a few other people on the island, including restaurant and maintenance personnel.

The participants were instructed to avoid social contact during a three-day period, and for this period, their laptops and online devices were collected for safe keeping. The participants could, however, play instruments, read books, take photographs, and walk around the island. Food was delivered three times a day without social contact. During the seclusion, any needs, worries, and requests were communicated via a notebook, and they mostly had to do with requests relating to food. Participants were instructed to maintain dream and mindwandering journals⁴ throughout this time. During seclusion, the participants did not have access to the online questionnaires and used a pen-and-paper method of collecting the reports instead. After seclusion, they transcribed the pen-and-paper reports to the online questionnaire, and the written reports were returned to the researchers.

To measure sleep parameters, the participants were given electroencephalography-based ZEO sleep monitor devices and instructed on their use. Zeo is a wireless sleep monitoring headband with three sensors to capture one-channel brain activity signals. It has been validated against polysomnography and actigraph data by using automatic, semiautomatic and manual systems of scoring (Griessenberger et al., 2013; Shambroom et al., 2012). ZEO accurately measures sleep parameters and its automated algorithm correctly categorizes stages of sleep, faring better than actigraph measures. There is, however, a tendency towards underestimating REM latency. ZEO seems poorer in detecting deep sleep and wake–sleep transitions at sleep onset or nocturnal awakenings (Griessenberger et al., 2013). ZEO devices were used throughout the retreat, and for the five additional nights at home following the retreat period. The sleep measures collected were total sleep time (TST), amount of REM, light and deep sleep, the number of awakenings, and sleep onset latency (SOL). Additionally, percentages of REM and deep sleep from TST were calculated. On Friday morning, upon the ending of the seclusion period, the participants filled a brief questionnaire about experiences during the period, the experience was debriefed and at noon the groups were returned to mainland. For five days, they continued the dream reporting procedure, which were included as post-seclusion reports, with an additional mindwandering report on the last day of the experiment.

⁴ The mindwandering reports are beyond the focus of this current study and will be part of another publication. Thus, the mindwandering report collection procedure is not elaborated here.

Content analysis

The dream reports were content analysed by two external blind raters using the *Social Content Scale*, devised to delineate various social situations in content reports (Tuominen, Stenberg, et al., 2019). The scoring procedure picks out social events, logs the interacting participants and their numbers, and categorizes the type and valence of the social situations. Disagreements were resolved via a consensus discussion between the raters. To avoid reporting biases due to personal concerns and worries of preserving anonymity, the participants were told the first and last authors would not participate in the content analyses. Two participants reported no dream reports and were removed from the subsequent dream content analyses.

PHQ-9

Presence of depressive symptoms was assessed using the Finnish version of the *Patient Health Questionnaire* (PHQ-9; Kroenke & Spitzer, 2002). PHQ-9 is a brief 9-item self-report questionnaire based on the 4th edition of the Diagnostic and statistical manual of mental disorders' diagnostic criteria for major depressive disorder. PHQ-9 is considered a reliable and valid measure of depression (Cameron, Crawford, Lawton, & Reid, 2008; Titov et al., 2011). Participants responded on a 4-point scale from 0 (Not at all) to 4 (Nearly every day). The sum score can vary between 0 and 24 points, where a score of 10 or greater is considered as indicative of the presence of major depressive disorder. The internal reliability (Cronbach's alpha) of the PHQ-9 total score was $\alpha = .73$, 95% CI [0.55, 0.90].

RFQ

Mentalizing abilities were assessed using the Finnish version of the brief *Reflective Functioning Questionnaire* (RFQ; Fonagy et al., 2016). Mentalization (i.e., reflective functioning) refers to the ability to interpret the intentional mental states of self and others. RFQ includes short claims (e.g., 'Sometimes I do things without really knowing why'), to which participants respond on a 7-point Likert scale from 1 (*Strongly disagree*) to 7 (*Strongly agree*). The RFQ scoring system was followed (Fonagy et al., 2016), where the scores can vary between 0 and 3 points. The scale consists of two factors: certainty about mental states (RFQ_C) and uncertainty about mental states (RFQ_U). Whereas RFQ_C is found to be related to attachment security and non-suicidal self-harm, RFQ_U is superior in predicting psychopathology, especially borderline personality disorder (BPD) diagnosis, and more severe forms of mentalization problems (Badoud et al., 2015; Fonagy et al., 2016). As our study excluded participants with diagnosed mental health disorders, we used the RFQ_C in our statistical models as a variable for mentalization abilities. The internal reliability (Cronbach's alpha) of the RFQ_C score was $\alpha = .68$, 95% CI [0.45, 0.91].

Need to belong

Belongingness was assessed using the Finnish version of the *Need to Belong* - questionnaire (NTB; Baumeister & Leary, 1995). The scale went through a back-translation procedure by the first author and a native-level English speaker. NTB is a self-report scale which includes short claims (e.g., 'I want other people to accept me'), to which participants respond on a 5-point Likert scale, ranging from 1 (not at all) to 5 (extremely). The sum score can vary between 10 and 50 points, with a higher score

indicating higher need to belong. The internal reliability (Cronbach's alpha) of the NTB total score was $\alpha = .86$, 95% CI [0.77, 0.96].

Ethical aspects

The research was carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from the participants after full explanation of the study procedure, and they were informed of their right to discontinue the study at any time should they so wish. Ethics Committee from the University approved the experimental protocol prior to the onset of the study. Due to the nature of the experiment, some additional considerations were undertaken. The participants were asked to assign emergency contact persons for the seclusion period in case of an urgent matter that would have required contact and breaking of the seclusion. The contact persons were in turn provided with the contact information for the researchers present at the island. Two researchers were available throughout the seclusion in case of emergencies, discontinuing in the study, or for other urgent matters. The seclusion contained briefing and debriefing sessions in a small group. After the study period, the participants were interviewed by a licensed psychologist for their experiences of the experiment, and possible additional questions that had arisen for the participants were answered. None of the participants discontinued the study during or after the seclusion, nor reported any negative or adverse effects.

Statistical analyses

Data were analysed with linear mixed-effects models (LMM) using the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015) in the R statistical software (Version 3.6.2). Separate models were built for the number of dream social interactions, number of strangers and known characters in dream interactions, number of positive and negative interactions in dreams, and the amount of REM sleep (percentage of total sleep time). The sociality bias ratio was calculated by dividing the number of dream interactions (5-point scale: 0 interactions = 1; 1–5 interactions = 2, 6–15 interactions = 3, 16–25 interactions = 4, and more than 25 = 5) with the number of wake interactions of the preceding day using the same grouping. A lower bias score (<1) indicates interactions as less frequent in dreams than throughout the preceding day, while a higher score (>1) indicates more frequent social interactions in dreams compared to the preceding day. Whereas previous research has indicated the presence of a sociality bias in comparing social interactions on a wake versus dream report level, here we wish to consider a broader ratio taking into account the whole rough estimate of the previous days' social interactions.

Due to a skewed distribution, a logarithmic transformation was performed to the sociality bias ratio prior to the analyses. Location (Pre-Seclusion vs. Seclusion vs. Post-Seclusion) was added to the models as a successive difference contrast coded fixed effects variable, except for the model on the amount of REM sleep location was added as treatment coded fixed effects variable (Post-Seclusion was set as baseline). PHQ-9, RFQ_C, and NTB scores were added to all models concerning dream content as centred fixed effects variables. The correlation between measures was modest (see Table 1). Only the main effect of the fixed effects variables was analysed. Participants were fitted in the models as random effects. The location was added to the models as by-participant random slope. If the model failed to converge, the random structure was trimmed starting with removing the correlation between the intercept and the slope (Brauer & Curtin, 2018).

Table 1. Descriptive statistics of the self-report measures

Measure	<i>M</i>	<i>SD</i>	Range	Correlation	
				PHQ-9	RFQ_C
PHQ-9	4.28	2.89	0–10		
RFQ_C	1.22	0.66	0.33–2.50	–.43	
NTB	28.56	7.04	11–37	.42	–.21

Note. NTB = Need to Belong Scale; PHQ-9 = Patient Health Questionnaire; RFQ_C = Reflective Functioning Questionnaire, certainty score.

The exact degrees of freedom are difficult to determine for the *t*- and *z*-statistics estimated by LMMS, leading to the problem of determining exact *p*-values (Baayen et al., 2008). Consequently, degrees of freedom, or *p*-values, are not reported; statistical significance at the .05 level is indicated by values of the $|t \text{ \& } z| > 1.96$. All final models are reported in Appendix S1. Further information, data sets, and the analysis scripts are made available via Open Science Framework (<https://osf.io/sx6yf/>).

Results

Descriptive statistics of the self-rated questionnaires are presented in Table 1. Overall, there were 303 dream reports, of which 289 (95.4%) included social situations. Of these 271, (93.8%) included social interaction simulations, while the rest were either social observations without interactions, or emotional reactions to such observations. There were on the average 5.8 social events and 4.4 social interactions reported per dream. Pre-seclusion dreams accounted for 31% ($N = 94$), seclusion dreams accounted for 29.7% ($N = 90$), and post-seclusion for 39.3% ($N = 119$) of all dream reports. It is noteworthy, that the only three seclusion reports (3.3%), which did not contain any social events, came from a single participant. The seclusion itself was successful, with only two participants reporting any wake social interactions during the seclusion period. The nine corresponding dream reports from these participants were removed from the data before analysis, leaving the total number of reports at 294, and seclusion reports at 81.

Dream recall varied slightly between conditions, with participants reporting more dreams during seclusion ($M = 1.77$, $SD = 0.90$) than pre- ($M = 0.93$, $SD = 0.30$) or post-seclusion ($M = 1.03$, $SD = 0.41$). The length of the dream reports overall was 151 words, ($SD = 156$) from 3 to 1,345 words, and varied between pre-seclusion ($M = 173$, $SD = 140$ range = 7–835), seclusion ($M = 123$, $SD = 99$, range = 5–485) and post-seclusion ($M = 163$, $SD = 199$, range = 3–1,345). For descriptive statistics of the dream and sleep variables, see Table 2, and for a detailed breakdown of the social contents of the dream reports, see Table 3. Immediately following the seclusion stage, the participants rated their experience on a 5-point Likert scale (1 = *completely agree*, 5 = *completely disagree*). They rated the seclusion retreat as *interesting* ($M = 4.4$, $SD = 0.7$), *relaxing* ($M = 4.3$, $SD = 0.7$), and *pleasant* ($M = 4$, $SD = 0.8$), instead of *frightening* ($M = 2$, $SD = 1.1$), *anxiety provoking* ($M = 1.9$, $SD = 1$), or *boring* ($M = 2.2$, $SD = 0.9$).

The model on *the number of dream interactions* testing the *Compensation Hypothesis* showed no effects of location, RFQ_C, PHQ-9, or NTB (for effect of location

Table 2. Descriptive statistics of dream and sleep variables

Measure	Pre-seclusion		Seclusion		Post-seclusion	
	M	SD	M	SD	M	SD
Interactions/dream	4.64	4.10	3.90	3.67	4.80	5.52
Dream/wake interactions	0.78	0.33	2.15	0.61	0.75	0.35
Positive interaction/dream	0.94	1.44	0.84	1.26	1.00	1.61
Negative interactions/dream	0.53	0.99	0.54	1.01	0.77	1.56
Total sleep time (min) ^a			409.12	86.46	402.35	97.70
REM (min) ^a			125.96	36.82	115.09	44.78
REM % ^a			0.31	0.06	0.28	0.07

Note. ^aDue to practical concerns sleep, data were not collected in pre-seclusion.

see Figure 1). However, the model on the *ratio between dream and wake social interactions* revealed three main effects. First, there was an effect of location indicating the *Sociality Bias* to be stronger during seclusion than in pre-seclusion, $\beta = 1.03$, 95% CI [0.91, 1.15], $t = 17.09$. Moreover, *Sociality Bias* was weaker in post-seclusion than during seclusion, $\beta = -1.09$, 95% CI [-1.20, -0.98], $t = -19.20$. In sum, during seclusion participants had more interactions in dreams than throughout the preceding day. This indicates that our social dream content remains relatively stable irrespective of the immediately surrounding social environment and does not merely mirror the contents of the previous day (see Figure 1). Second, the model revealed a main effect of RFQ_C, indicating that when RFQ_C score increased participants showed more dream interactions than actual interactions during the preceding day, $\beta = 0.09$, 95% CI [0.01, 0.16], $t = 2.33$. The model did not show effects for PHQ-9 or NTB. Combined mean over all conditions for Sociality Bias was 1.14 ($SD = 0.75$), indicating more interactions in dream reports than throughout the preceding days.

Testing the *Strengthening Hypothesis* for the participants' dream interactions, the model on *the likelihood of strangers in dreams* showed less strangers in dreams during seclusion than in pre-seclusion condition, $\beta = -0.29$, 95% CI [-0.55, -0.02], $z = -2.10$ (see Figure 2A). However, the model showed no difference between seclusion and post-seclusion conditions, $\beta = 0.22$, 95% CI [-0.04, 0.47], $z = 1.65$. The model did not show effects for either RFQ_C, PHQ-9, or NTB. The model on *the likelihood of known characters in dream* showed no effects (effect of location is illustrated in Figure 2B). The model on the *number of negative interactions in dreams* showed a main effect for RFQ_C. This indicates an increase in the RFQ_C score corresponding to an increase in the number of negative interactions in dream reports, $\beta = 0.36$, 95% CI [0.14, 0.58], $z = 3.16$. The model did not show any effect of either location, RFQ_C, NTB, or PHQ-9 (effect of location is illustrated in Figure 2C). Last, the model on the *number of positive interactions in dreams* did not show any effects (effect of location is illustrated in Figure 2D).

Turning from dream contents to the amount of REM sleep, two observations were removed from the model due to likely loss of electrode contact. One showed 0 min of REM sleep and the other showed only 48 min of sleep in total (6 min of REM sleep). The model on *the amount of REM sleep* revealed a main effect of location indicating that participants showed higher proportion of REM sleep during the seclusion than in the post-seclusion condition, $\beta = 0.03$, 95% CI [0.01, 0.05], $t = 2.95$ (see Figure 3).

Table 3. Social dream content categories

Measure	Pre-seclusion			Seclusion			Post-seclusion		
	% Dreams	% Soc Events	N	% Dreams	% Soc Events	N	% Dreams	% Soc Events	N
Social content	98.1%	100%	586	96.7%	100%	442	93.2%	100%	730
Social interactions	90.4%	74.4%	436	87.7%	75.3%	316	88.2%	78.2%	571
Neutral	88.3%	68.3%	298	77.8%	64.6%	204	83.2%	63.0%	360
Positive	44.7%	20.2%	88	46.9%	21.6%	68	49.6	20.1%	119
Physical affection ^a		3.4%	3		2.9%	2		3.4%	4
Verbal affection ^a		10.2%	9		7.4%	5		4.2%	5
Welcome sexual interaction ^a		13.6%	12		2.9%	2		11.8%	14
Cooperative or altruistic behaviour ^a		44.3%	39		54.4%	37		41.2%	49
Approach cues ^a		10.2%	9		11.8%	8		13.4%	16
Request for support ^a		12.5%	11		16.2%	11		20.2%	24
Mediating behaviour ^a		5.7%	5		4.4%	3		5.9%	7
Negative	29.8%	11.5%	50	33.3%	13.9%	44	37.0%	16.1%	92
Physical aggression ^a		18%	9		20.5%	9		30.4%	28
Verbal aggression ^a		26%	13		31.8%	14		23.9%	22
Forcing, obstructing ^a		4.0%	2		0%	0		5.4%	5
Unwelcome sexual interaction ^a		2.0%	1		0%	0		0%	0
Avoidance behaviour ^a		20.0%	10		13.6%	6		22.8%	21
Abandonment, rejection ^a		30.0%	15		34.1%	15		17.4%	16
Interactions familiar ^b	67.4%	70.2%	306	70.4%	81.6%	258	74.8%	77.9%	445
Family ^a		24.8%	76		37.2%	96		29.2%	130
Spouse/partner ^a		9.5%	29		5.8%	15		10.3%	46
Friends ^a		65.7%	201		57.0%	147		60.4%	269
Interactions/strangers ^b	78.7%	81.4%	355	64.2%	67.1%	212	71.4%	78.6%	449
Interpersonal emotion	38.9%	10.2%	45	45.6%	12.2%	54	39.0%	6.6%	79
Positive ^a		24.4%	11		29.6%	16		29.1%	23
Negative ^a		75.6%	34		70.4%	38		70.1%	56

Note. ^aOf the higher order category; ^bn.b. interactions may contain several simultaneous characters ($N^{\text{pre}} = 755$; $N^{\text{seclusion}} = 527$; $N^{\text{post}} = 989$).

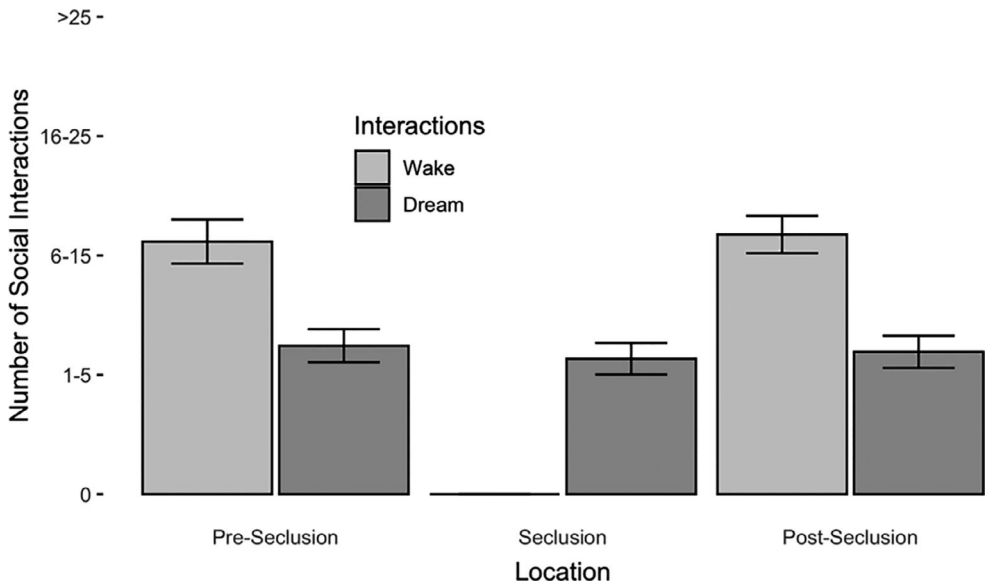


Figure 1. The number of wake and dream social interactions before, during, and after seclusion. Dream interactions consider the number of social interactions in dream reports, wake interactions the total amount of estimated social interactions throughout the day. Error bars represent 95% confidence intervals.

Discussion

Controlled seclusion was used to assess the effects of drastic decreases in social wake interactions on social dream contents and sleep structure. Three specific hypotheses of the SST (Revonsuo et al., 2016a; Tuominen, Stenberg, et al., 2019), and one on sleep structure changes were tested.

First, the strong version of SST *Compensation Hypothesis* – which predicts a decrease in the number of social interactions in waking life to increase subsequent social events in dreams – did not gain support. In fact, a lower absolute number of dream social interactions was found during the seclusion retreat. One explanation for this may be that the seclusion period was either too short or too pleasant to activate a threat to social exclusion. There was no actual risk of the participants to be subjected to group abandonment, but merely the concrete lack of the physical presence of others. In fact, the participants rated the experience as an overall positive experience. Thus, before assigning the compensation hypothesis as debunked, we should carry out experiments in natural settings where real-life exclusion would be at stake. In this study, however, the strong form of the hypothesis does not hold.

Second, the *Sociality Bias* was shown to be relatively robust against drastic changes in social environments, with the interesting additional finding that depressive symptoms correlate with a decreased sociality bias in dreams. This is in line with the previous research on fewer characters in dreams of depressed patients (Barrett & Loeffler, 1992). As our study consisted of participants without psychiatric diagnoses, this finding suggests the tendency to be present in the subclinical range of symptoms. Interestingly, a study on 12 psychotically depressed patients found more, and only, family members in dreams compared to other patient groups (Langs, 1966). Overall, the number of social encounters

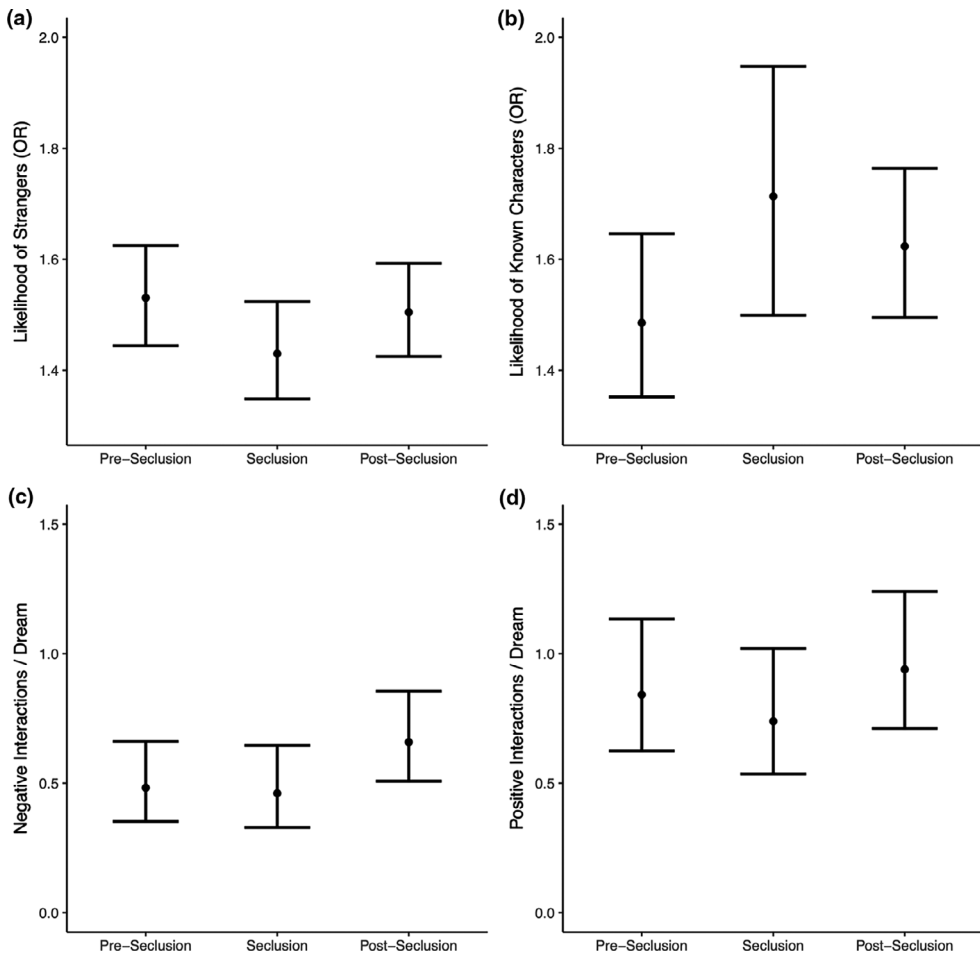


Figure 2. The effect of seclusion to (A) *Likelihood of Strangers in Dreams* as Odds Ratios, (B) *Likelihood of Known Characters in Dreams* as Odds Ratios, (C) *Number of Negative Interactions* (C), and *Number of Positive Interaction* (D). Y-axes represent model estimates, and error bars represent 95% confidence intervals.

and characters in our dreams seems to remain relatively stable, despite drastic changes in external social circumstances. It remains to be tested whether this also holds for other task-unrelated processes, such as mindwandering or daydreaming, or whether it is an especially dream-related feature.

Third, the *Strengthening Hypothesis* was partially supported, as under seclusion we seem to simulate less interactions with strangers compared to pre-seclusion. This finding increases the specificity of SST and supports its supposed content selection mechanism. During a large shift in our social environment, we fall back to simulating interactions with non-strangers. This sheds light on the previous attempt at analysing the ratio between strangers and familiar characters in a setting with no experimental manipulation (Tuominen, Stenberg, et al., 2019). One could reformulate the hypothesis more specifically: When close relationships are secure and active, we are more likely to simulate interactions with strangers. When these relationships are severed, we return to strengthening them via increased simulations during dreams. This fits with results from

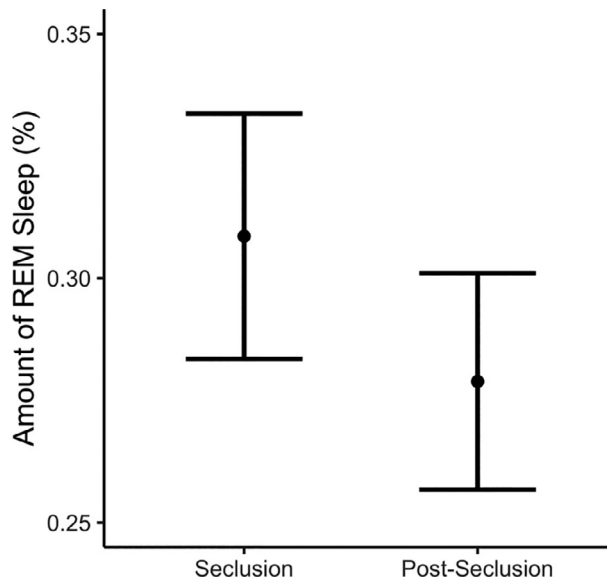


Figure 3. The effect of seclusion for the *Amount of REM sleep (%)*. Y-axis represents model estimates, and error bars represent 95% confidence intervals.

Mérei (1994) and with retrospective accounts of WWII concentration camp survivors (Bergman et al., 2020), as in both samples dreams contained more family members under imprisonment than afterwards.

Fourth, there were no differences in the number of negative or positive dream interactions. However, mentalizing ability was correlated with the number of negative social interactions in dreams. As RFQ_C is negatively correlated with insecure attachment, this finding stands in contrast to previous studies. Mikulincer, Shaver, and Avihou-Kanza (2011) found anxiously attached peoples' dreams to contain more negative other representations, especially following stressful events. However, RFQ_C captures a facet of relating to other people beyond attachment anxiety. As such, the interplay between social dreams and mentalization requires further study. An underlying broader capability may allow for both, the certainty of others' mental states, and for more complex negatively valenced social simulations. Alternatively, the capacity to consider counterfactual negative interactions with others may allow for more accurate mental state representations.

Finally, REM sleep increased during social seclusion, concurring with the results from Wood (1962) despite studied in a different setting (research laboratory vs. natural environment). Furthermore, we are able to disassociate this finding from the increase in social dream activity. What, then, would explain the differences in amount of REM sleep? McNamara's (1996) suggestion on the attachment functions of REM sleep could be on a very general level considered to fit the finding of more family members present in dream reports from the seclusion period, yet this should be considered a tentative explanation and would require further study.

Here, we have explicitly approached these hypotheses from the perspective of SST. However, as the theories in dream research in general are often not mutually exclusive, one could also approach these findings from competing viewpoints. From the viewpoint

of TST, we could consider lack of social connection as a social threat that should increase threatening social simulations in dreams. Here, we aimed to decrease the amount of actual social threat by structuring the experiment to be as pleasant and predictable for the participants as possible. Given the current COVID-19 pandemic, it would be interesting to compare voluntary and involuntary social seclusion or isolation controlling for the experienced fear of exclusion and loneliness. Thus far, one study has compared COVID dreams to a similar previous sample using TST, SST, and ICH as theoretical viewpoints and found support for predictions of both TST (increased frequency of threatening events) and SST (maintenance of positive and neutral social interactions), but not for ICH (no increase of illness or disease contents; Wang et al., 2021). However, this study lacked a control for the amount of social interactions the participant had experienced during the day.

Our waking mind reacts to changes in the environment as we adjust to new circumstances. As noted in the introduction the Continuity Hypotheses would argue that either these actual concrete events (ICH) or the cognitive concerns (CCH) caused by the seclusion should be mirrored in dream content, without the need to posit additional functions for dreaming separate from the functions of the waking mind. In this study, we did not explicitly assess the current concerns and wake cognitive contents (CCH) as it was not the theoretical framework we were functioning under. However, a future analysis of the mind-wandering reports from this period could help illuminate this topic further. The more strict ICH cannot be considered to have gained support from our study, as a radical decrease in social contacts did not cause a corresponding collapse of social dream contents. Finally, emotion regulation theories posit the function of dreams to be in adjusting our emotional responses. The predictions from ERT are not necessarily mutually exclusive from those of SST as there is clear overlap between the viewpoints. In conclusion, there are several theories of dream function which may either differ in their theoretical presuppositions yet predict similar contents, or may share a theoretical model yet concentrate on different aspects of dream contents. In this study, we made the decision to concentrate on the theory that bears most strongly on social dream contents, SST. Future studies more directly comparing and contesting predictions and background assumptions from various theories is clearly in order. As suggested by Revonsuo, Tuominen, and Valli (2016b), such a development would lead to a clarification and possible unification of competing theories. Such a path would likely provide a more robust and covering theoretical model to steer research in the dream sciences.

Limitations to the study

As with most dream research, the main issue is the small sample size. Thus, these findings should be considered preliminary and be independently replicated. This study also had additional feasibility concerns due to the financial and practical requirements of the research setting. Time resources required likely contributed towards selection bias for motivated participants. Additionally, we were not able to control for the effect of the retreat location itself. Future studies should include a control group that follows a similar procedure excluding seclusion. Further, as we concentrated on the biological function postulated by SST, we did not collect data on the current concerns of the participants, which would have allowed us to compare the continuity between waking concerns and dream content. Similarly, more strict form of compensation hypothesis remains to be tested in, for example, a naturally occurring situation of group exclusion or risk thereof.

Conclusion

Social seclusion alters dream content and sleep structure. The strong version of the *Compensation Hypothesis* failed to gain support, with social situations in dreams decreasing during seclusion. Simultaneously, however, the number of unknown characters decreased, and the amount of REM sleep increased. Additionally, the contents of dreams remained socially biased even under seclusion, suggesting a discontinuity between wake experiences and dream content. Strength of this bias was moderated by depressive symptoms. Negative social dream content was related to the certainty of others' mental states. Future research should replicate these findings, test more sensitive hypotheses of the theory, and compare dreams with other task-unrelated cognitions. Furthermore, comparisons between dream theories should be undertaken to assess the strengths, weaknesses, and possible integration of viewpoints.

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Conflicts of interest

All authors declare no conflict of interest.

Author contributions

Jarno Tuominen (Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Writing – original draft) Henri Olkonieni (Data curation; Formal analysis; Methodology; Writing – original draft) Antti Revonsuo (Conceptualization; Investigation; Methodology; Project administration; Supervision; Writing – original draft) Katja Valli (Conceptualization; Data curation; Investigation; Methodology; Project administration; Supervision; Writing – original draft).

Data availability statement

Data available in a public repository at Open Science Framework (<https://osf.io/sx6yf/>).

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Supporting Information

The following supporting information may be found in the online edition of the article:

Appendix S1. Final models for each measure.