Emotional valence affects the day-residue and dream-lag effects

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Summary. There are two temporal delay effects used to describe the reoccurrence of day events in dreams. The day-residue effect is the reflection of events in dreams 1-2 nights after its occurrence and has been observed in typical and unusual day events. The dream-lag effect is the re-surfacing of daily events approximately a week after and more likely to occur when personally significant events are encountered. Further, degree of emotional intensity affects likelihood of day incorporation. The current study explores the temporal pattern of incorporation of emotionally salient day events. A sample of undergraduate psychology students (N = 45) completed a daily journal of events containing emotional importance. Nightly dream journals were also maintained for one week and were required to include as much detail as possible. Independent judges rated the number of correspondences between day events and the subsequent 7 dreams. Analysis revealed a main effect of day, main effect of emotion; negative emotions ($p < 0.05$) and neutral items ($p < 0.01$) were much more likely to be incorporated in dreams than positive emotions. In addition, there were significantly more incorporations on day 1 versus day 5 ($p < 0.05$) and day 7 ($p < 0.05$) for both negative and neutral correspondences. Overall, correspondences indicated a day-residue effect, but no dream-lag effect.

Keywords: Dream-lag, day-residue, dreams, emotion, emotional salience

1. Introduction

Research suggests a relationship between dream content and waking day, which has been widely supported across various samples (Antunes-Alves & De Koninck, 2012; DeCicco, Lyons, Pannier, Wright, & Clarke, 2010; Schredl & Hofmann, 2003). Both REM and NREM sleep are implicated in learning and memory (Nader, Murkar, & Smith, 2016), and elements of waking day experiences, such as emotions or a significant event may be incorporated into nightly dreams as a function of memory consolidation during critical times of Rapid Eye Movement (REM), Slow wave Sleep (SWS; Diekelmann & Born, 2010; Gais & Born, 2004; Murkar, Smith, Dale, & Miller, 2014a). A hypothesized underlying mechanism to the temporal delay in memory is explained by the relocation of event memories from the hippocampus, to the neocortex-a process that takes roughly one week after the initial waking-day event (Nielsen & Stenstrom, 2005). REM sleep is implicated in the processing of emotional memory, and it has been suggested that dreams may in part reflect this (Murkar & De Koninck, 2018; Murkar, Smith, Dale, & Miller, 2014b). To that end, there are two forms of temporal delays: the day-residue effect and the dream-lag effect.

The day-residue effect is the reappearance of life events in dreams immediately following the occurrence of such event (Nielsen, Kuiken, Alain, Stenstrom, & Powell, 2004). Incorporations of emotionally negative day events are significantly higher on the first night than any other subsequent day (Nielsen & Powell, 1992). Nielsen et al. (2004) found dream correspondences were high on dream days 1 and 2, compared to days 3 and 4 in participants with high memory confidence. Further, day residues have been observed when day events containing some sort of personal and/or emotional importance to the dreamer (Nielsen & Powell, 1988; 1992; Nielsen et al., 2004). Conversely, day residue effects have been observed in correspondences of mundane waking day events (Vallat, Chatard, Blagrove, & Ruby, 2017). The day-residue effect has been observed when recording dreams both in one's home as well as in an unfamiliar environment such as a sleep lab (Nielsen & Powell, 1989). As such, the day-residue effect has been found to occur regardless of surroundings (novel versus familiar) and nature of the day event (mundane versus emotionally significant).

The dream-lag effect refers to the reappearance of waking day events in dreams 5-7 days after its initial occurrence (Nielsen et al., 2004). It has been suggested that qualitatively different day events are found to incorporate at different rates (Marquardt, Bonato, & Hoffmann, 1996; Nielsen et al., 2004). When important day events are not specified to be recorded by participants, no such dream-lag effect was found (Henley-Einion & Blagrove, 2014). However, when accounting for significant or unusual day events, proportion of waking day residues are higher 5-7 days compared to 2-4 days (Nielsen et al., 2004; van Rijn et al., 2015). For instance, incorporation of day events 5-7 days after its occurrence was found for personally significant events, but not for major daily activities, or major concerns, which are of

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less salience (van Rijn et al., 2015). Furthermore, individuals with high memory confidence exhibited a dream-lag effect amongst events pertaining to interpersonal relationships and problems resolved but not for spatial locations or self-actions (Nielsen et al., 2004). Such findings imply that the aforementioned recalled events contain more emotional intensity, and as such, more likely to follow a temporal delay.

The Continuity Hypothesis posits that events and emotions from waking day experiences are incorporated into dreams (Hall & Nordby, 1972); many studies have observed that waking-day events are incorporated into dreaming (Black, Murkar, & Black, 2014; Dale, Murkar, Miller, & Black, 2014; DeCicco, Zanasi, Dale, Murkar, Longo, & Testoni, 2013; Salem, DeCicco, Ragab, Yousif, Murkar, & Vaswani, 2013). This also applies to one's mental state. Individuals with lower psychological well-being dream of more negative emotions, aggression, and frequent nightmares (Antunes-Alves & De Koninck, 2012; Pesant & Zadra, 2006). Dreams of depressive and anxious themes, for example, include fear and anxiety experienced during the day (Schredl & Engelhardt, 2001). Dream content is also influenced by stress experienced in waking day such as battling cancer (DeCicco et al., 2010) or going through a divorce (Cartwright, Agargun, Kirkby, & Friedman, 2006).

Moreover, studies have found that the emotional intensity of daily events is an important determinant of subsequent dream content as it increases the probability events being incorporated (Schredl, 2006; Schredl & Reinhard, 2009). Day experiences incorporated into dreams are significantly more emotionally intense than those not incorporated (Malinowski & Horton, 2014; Eichenlaub et al., 2018). Further, majority of waking day events being incorporated into dreams have been scored moderate to highly emotionally intense by dreamers themselves (Vallat et al., 2017). These findings support the notion that emotional intensity - not valence - contributes to dream incorporation. Many theories have explored this effect, suggesting that emotions are a marker of significance of an experience and as such, warrants further processing (see Malinowski & Horton, 2015 for a review). Amongst them, one is the theory of emotion-assimilation function of sleep: emotional waking day events preferentially re-surface in dreams to be acquired into the wider memory system (Malinowski & Horton, 2015). This has been supported when investigating memory as images of high arousal and positive valence are remembered more than neutral images (Atienza & Cantero, 2008). This extends to dream recall as incorporations of waking-day events beyond 1-2 days have contained interactions, resolution and positive emotions-all of which imply some sort of emotional meaning (Nielsen et al., 2004).

Studies have consistently found daily incorporations in dreams immediately following the event, supporting the day-residue effect (Blagrove, Henley-Enion, et al., 2011; Henley-Einion & Blagrove, 2014; Marquardt et al., 1996; Nielsen et al., 2004); however, further research is required in order to elucidate the conditions influencing day-residue and dream-lag. Research has consistently suggested that waking events with emotional significance are more likely to be incorporated in dreams (Malinowski & Horton, 2014; Schredl, 2006; van Rijn et al., 2015).

While researchers have emphasized the importance of considering emotional significance of dreams when observing temporal delay effects (Nielsen et al., 2004), this has been less well explored within the context of day-residue. As research has observed a bias in dreams towards negative emotional content (Valli, Strandholm, Sillanmäki, & Revonsuo, 2008), other research has found that emotional intensity affects dream incorporation more than valence (Malinowski & Horton, 2014; Schredl, 2006; Schredl & Reinhard, 2009). The present study examines whether the patterns of temporal delay are the same for positive and negative emotions.

Consistent with previous findings that emotional intensity influences dream incorporation (Schredl & Doll, 1998), we hypothesized that emotionally salient day events will correspond to subsequent dream imagery as both a day-residue and dream-lag effect. Comparisons of negative emotions, positive emotions, and neutral items within the context of dream-lag and day-residue were exploratory in nature.

2. Method

2.1. Participants

Forty-five (7 males, 38 females) undergraduate students enrolled in psychology courses were recruited from Trent University to participate. Majority of participants were single (64%), first year students (58%), and between 18-19 years of age (67%). Participant ages ranged from 18-25 years old (M = 19.42; SD = 1.61). Students received additional course credit for their participation.

Dream lengths on average were 75.14 words. Participants reported a total of 142 emotionally salient events in the day 1 waking-day event journals. The mean number of emotionally salient events on day 1 reported by each participant was 3.16 (SD = 1.66; range = 0-7). A total of 269 dreams were reported by participants across the 7 recording nights. The mean number of dreams reported by each participant was 5.98 (SD = 2.42; range = 1-15). 120 emotions were reported in total, of those, 16% were positive (N= 19), 84% were negative (N = 101). On average, individuals had 0.42 positive emotions and 2.24 negative emotions in dreams in total across the 7 days.

2.2. Materials

A demographics questionnaire assessed participants' age, race/ethnicity, education level, occupation and marital status. Participants completed a daily journal for 7 days. The daily journal instructions were not adapted from previous research. For day events, participants were instructed to date and record all day events that trigger significant emotions (e.g., got into a fight with a significant other), including as much detail as they feel comfortable. For dreams, participants were instructed to record all dreams each time after awakening from sleep. They were to include as much detail as possible including emotion, sounds, colours, and surroundings.

2.3. Procedure

All participants collected their packages and maintained a dream journal for one week, recording daily events and nightly dreams. Only the day events from the first day were of interest in order to assess the dream-lag effect. The number of correspondences between participants' daily events from day one and the subsequent 7 nightly dreams were recorded. The dreams were content analyzed, using Hall and Van de Castle's (1966) scoring guidelines, in that

only explicit mention of category items were scored. Scoring was checked for reliability against a second coder on the same data set. Inter-rater reliability was calculated as the total number of agreements divided by the total number of observations. Inter-rater reliability was 85%, which was considered acceptable. The minimum recommended value for inter-rater reliability using this method of calculation is 70% (Spata, 2003). Dreams were analyzed using the following categories of correspondences: negative emotion, positive emotion and neutral items. A positive or negative emotion correspondence was considered only if explicit mention of emotions recorded from the day were also noted in a dream (e.g., clearly stating one was feeling "scared" in a dream would be scored as a negative emotion correspondence; feeling "happy" was a positive emotion correspondence). Any mention of people or objects, which did not fall under either negative or positive categories were coded as a neutral item correspondence (e.g. any mention of specific friends, family, and objects in dreams that were involved in the day event). Total number of negative emotion, positive emotion, and neutral item correspondences were recorded.

2.4. Analyses

All statistical analyses were conducted using IBM Statistics Package for the Social Sciences® (SPSS) 20. Data were analyzed through mixed-measures and repeated-measures analysis of variance (ANOVA) in which the repeated measures factor was days since the waking-day event and correspondence category and between-group factor was incorporation type (negative, positive, neutral). Follow-up comparisons of significant main effects or simple effects of significant interactions were conducted using Bonferroni corrected t-tests or Games-Howell tests where assumptions had been violated.

3. Results

Figure 1 shows correspondences for dreams across the 7 nights following the events of the day 1 journal. Mauchly's test revealed that the assumption of sphericity was violated, $p < 0.05$. Greenhouse-Geisser corrected analysis revealed a main effect of day, $F(4.3, 561.4) = 4.113$, $p < 0.05$. Analyses also revealed a significant main effect of group, $F(2, 132) = 17.064$, $p < 0.001$. There was no significant interaction effect.

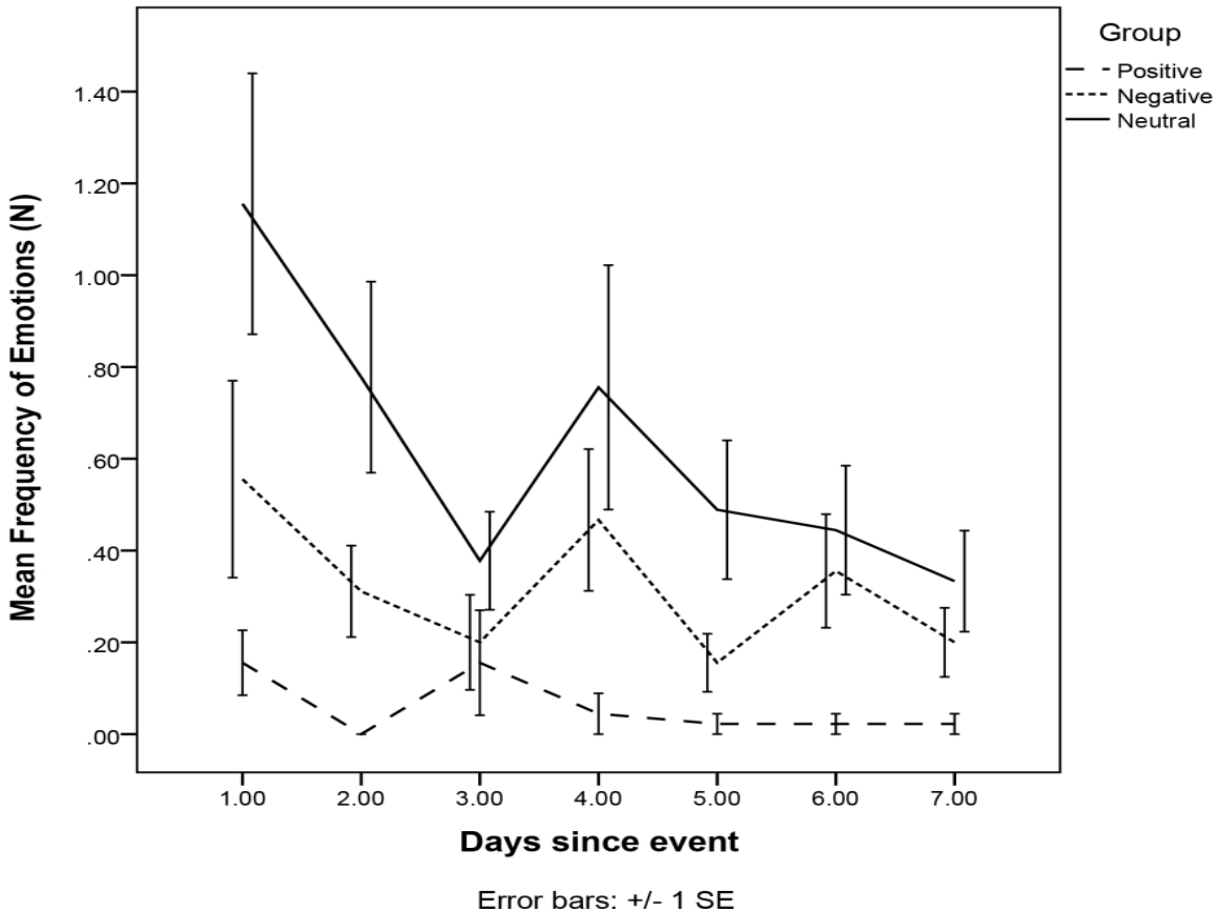

Figure 1. Mean frequency of emotions across 7 days following waking-day events. Overall, there were significantly more incorporations for negative emotions ($p < 0.05$) and neutral items ($p < 0.01$) versus positive emotions. Evidence suggests a day-residue effect, since there were significantly more incorporations on day 1 versus day 5 ($p < 0.05$) and day 7 ($p < 0.05$) for both negative emotions and neutral items. However, a significant dream-lag effect was not observed on days 5-7 (all $p > 0.05$).

Follow-up analyses indicated that there were significantly more incorporations for negative ($p < 0.05$) and neutral ($p < 0.01$) versus positive overall, suggesting that negative emotions and neutral items were much more likely to be incorporated in dreams than positive emotions. In addition, there were significantly more incorporations on day 1 versus day 5 ($p < 0.05$) and day 7 ($p < 0.05$) for both negative and neutral (but not positive) correspondences. This suggests the presence of a day-residue effect for negative emotions and neutral items. However, a significant dream-lag effect was not observed on days 5-7 (all $p > 0.05$).

Figure 2 shows total correspondences overall for the 7 days following the events of the Day 1 journal. Mauchly's test revealed the assumption of sphericity had been violated, $p < 0.05$. Greenhouse-Geisser corrected ANOVA revealed a significant main effect of day, $F(3.8, 167.1) = 3.314$, $p < 0.05$.

Follow-up analyses indicated that there were significantly more incorporations on day 1 versus days 3, 5, 6, and 7 (all $p < 0.05$), indicating a day-residue effect for total incorporations. However, analyses did not reveal a significant increase in correspondences later in the week (all $p > 0.05$).

4. Discussion

The aim of this study was to explore the temporal patterns of incorporation of emotionally salient events in comparison to previous findings, which have examined a variety of day events (Blagrove, Henley-Enion et al., 2011; Nielsen et al., 2004; van Rijn et al., 2015). Consistent with past research, a day-residue effect was observed, as total incorporations were significantly higher on day 1 compared to days later in the week. Specifically, the day-residue effect was found for negative emotions and neutral items, but not for positive emotions. The finding of immediate recall of neutral items is consistent with past research, which has found that familiar environments and daily activities are incorporated at a day-residue rate (Blagrove, Henley-Enion et al., 2011; Vallat et al., 2017). However past research has also found the day-residue effect for unusual or personally important day events being more likely to incorporate into dreams (Nielsen et al., 2004; van Rijn et al., 2015); our results would seem to support this for negative emotions, but not positive.

Malinowski and Horton's (2014) findings suggest that highly stressful experiences are highly emotional, but not all highly emotional experiences are highly stressful, especially positive. Therefore, participants' own meaning of stress may not always be activated when experiencing an event perceived as highly emotional. Perhaps this is the case for the current sample in that positive emotions experienced during the day did not exceed one's threshold and thus were not recalled to the same degree as negative emotions and neutral items. Moreover, van Rijn et al. (2015) found that only participants who were worried about being in a sleep-lab dreamt about it despite the overall experience deviating from usual daily events. Further, the sample consisted of students, who are more often exposed to negative emotions such as stress and worry (Reavley & Jorne, 2010). Since the current sample consisted of university students, such

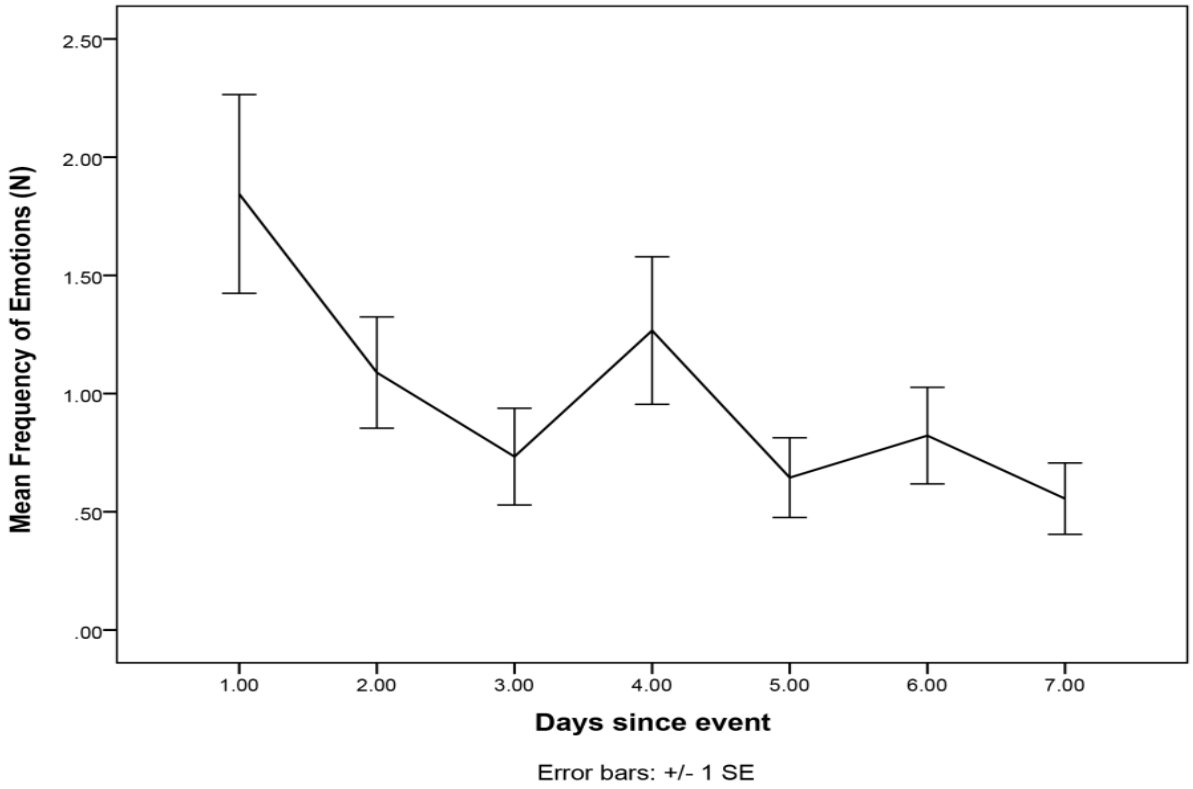

Figure 2. Overall incorporations were more frequent on Day 1 versus days 3, 5, 6, and 7, all $p < 0.05$; this is consistent with day-residue. However, findings indicated no significant effects later in the week that would be consistent with a dream-lag effect.

evidence can support why more negative and neutral items were recalled more overall.

Curiously, our paper did not support the 'intensity-not-valence' effect that has been reported by other groups. Overall, significantly more incorporation of negative emotions and neutral items was found compared to positive emotions. This is in contrast to previous research supporting that intense emotions from the day will be incorporated into dreams, regardless of valence (Malinowski & Horton, 2014; Schredl, 2006; Schredl & Reinhard, 2009) and recalled in dreams 1-2 days following the event (Nielsen & Powell, 1992; Nielsen et al., 2004; van Rijn et al., 2015).

There are several possible explanations for this. Fear and anxiety are largely mediated by central networks of the amygdala, which interact directly with hormone secreting structures of the hypothalamic-pituitary-adrenal axis (HPA-axis) via input to the periventricular nucleus (PVN; Cole & Sawchenko, 2002; Decavel & Van Den Pol, 1990; Herman, Cullinan, Ziegler, & Tasker, 2002). In contrast, positive emotions are more dependent upon dopaminergic structures such as the reward network (i.e. nucleus accumbens). We have previously suggested that the REM-dependent processing of emotional memory may include an evolved adaptive prioritization of memories that would aid in survival (Murkar & De Koninck, 2018). In this context, the prioritization of memories with negative valence makes sense.

The actual mediator of the relationship between valence, intensity, and dream content would thus instead be the secretion of neurohormones during intense emotional expression (at encoding) and during sleep, rather than the perceived intensity or valence of the emotion per se (which would simply correlate with dream content appearing during sleep-dependent processing of memories that were "tagged" during waking-day HPA-axis activation). The mechanisms for this process have in fact already been tentatively identified: the secretion of cortisol during both encoding and sleep enhances subsequent memory for stressful events (Buchanan & Lovallo, 2001; Roozendaal, Williams, & McGaugh, 1999; van Marle, Hermans, Qin, Overeem, & Fernández, 2013), and competitive interaction of the hippocampus and striatum are responsible for "tagging" procedural memories for subsequent consolidation during sleep (Albouy et al., 2013) – although it has not been determined whether this (or a similar) mechanism applies to emotional memory. As a result, if dreams do simply reflect memory processing as we suggest (Murkar & De Koninck, 2018; Murkar, Smith, Dale, & Miller, 2014a), our findings may simply mirror the fact that negative events are somewhat more likely to trigger a stress response that affects subsequent memory processing than positive events (for a more thorough review of REM and emotional memory processing see Murkar & De Koninck, 2018).

It is also possible that this disagreement may be attributed to the common finding that emotions are underestimated when judges are used in rating dreams (Sikka, Valli, Virta, Revonsuo, 2014), especially for positive emotions (Röver & Schredl, 2017; Schredl & Doll, 1998). Further, participants were instructed to record dreams in as much detail as possible, and as such may not have reported explicit emotions because they were not probed to do so (Sikka et al., 2014). Therefore, judges would only recognize emotions of explicit mention and potentially fall victim to the negativity bias (Sikka et al., 2014; Sikka, Feilhauer, Valli, & Revonsuo, 2017). However, there was a day-residue effect for neutral items. The incorporation of certain people and settings from emotionally salient day events provides further support to the day-residue effect, but also that aspects of the day associated with emotional significance will re-surface in dreams (van Rijn et al., 2015).

Although many studies have observed the dream-lag effect, others have only found weak-to no effects (Nielsen & Powell, 1989; 1992; Vallat et al., 2017). Therefore, uncertainty still remains in regard to the dream-lag being a consistent effect in temporal delays of dreaming. The current study did not replicate a dream-lag effect, as overall total emotion correspondences were significantly higher immediately after the event, but not 5-7 days later. Further, a dream-lag effect was not found when considering either emotions or neutral items. This is surprising, since some previous research has observed a dream lag effect for day events containing emotional significance of some sort (Nielsen et al., 2004; van Rijn et al, 2015). Although our findings suggested a slight increase for neutral items and negative emotion incorporations on day 4, the trend was non-significant and the increases on day 4 fall outside of the 5-7-day window. It has been suggested that emotional stimuli can be re-activated in different contexts during sleep and as such, are better remembered in short term therefore, emotional intensity is reduced over time due to the assimilation process (Malinowski & Horton, 2015). Similarly, the emotional tone of memories has been addressed by other research such that emotional tones diminish over time in sleep (Walker, 2009). The fact that no dream lag effect was found in the current study may support these notions. Although emotional intensity can increase waking day incorporation (Schredl, 2006; Schredl & Reinhard, 2009), perhaps no dream lag effect was found amongst emotionally salient events because such emotional strength was weakened towards the end of the 7 day-period.

Mixed findings of the dream-lag effect may be attributed to methodological differences in regard to who measures day correspondences. A significant dream-lag effect has been found in participants' own ratings of correspondences but not in judges' observations (Blagrove, Henley-Einion et al., 2011, Nielsen & Powell, 1989). Similarly, independent judges' observations supported the day-residue effect, but not the dream-lag in other work (Blagrove et al., 2011; Nielsen & Powell, 1989;1992). Conversely, a dream-lag effect was observed in a laboratory setting in one study (Nielsen & Powell, 1989); however, more recently this effect was not replicated in the lab (van Rijn et al., 2015). In this respect, our findings on dream-lag were consistent with Blagrove et al. (2011).

Although compelling, our findings here are not without limitation. The correspondences of interest included positive emotions, negative emotions, and neutral items. Although the first two are clear as to what it consists of, the latter variable implies that reoccurrence of people/objects in dreams are neutral. However, since dreamers did not self-rate category items for emotion, these items may not truly be neutral. Future designs could benefit from further analyzing such content to consider self-ratings of emotional intensity and valence of neutral items.

The current study only used independent judges for rating day/dream correspondences. Daytime incorporations differ in dreams immediately following the event versus one week later; dream-lag incorporations require different and slower processing, creating some distortion, as suggested by previous researchers (Blagrove, Henley-Einion et al., 2011;

Marquardt et al., 1996). For instance, memory consolidation in sleep may not always reflect identical components from a waking experience (Wamsley, Tucker, Payne, Benavides, & Stickgold, 2010). As such, distortions or abstract images may be better understood and identified by dreamers themselves, rather than an independent judge (Blagrove, Henley-Einion, et al., 2011). Furthermore, independent judges could be more biased to negative emotions and tend to overestimate negative emotion correspondences compared to dreamer's self-reports (Schredl & Doll, 1998; Sikka et al., 2014; Sikka et al., 2017). This could possibly explain why we found that overall more negative than positive emotions were recalled in dreams. Despite this, the use of an independent judge is not a complete disadvantage. A rigid text-based analysis prevents potential biases of the dreamer. Although our study did not include individuals' own rating of emotions in the dream, future studies would benefit from incorporating and comparing both methods with the same data set.

Our sample also had a high ration of females to males; this is typical in this area of research (Nielsen et al., 2004; Schredl, 2006; Schredl & Reinhard, 2009; Vallat et al., 2017). With this in mind, it may be unsurprising to find more negative emotions recalled in dreams from the current sample as females have been found to report more negative than positive emotions in dreams (Sikka et al., 2017). This may pose issues towards generalizability of these dream effects, as researchers have acknowledged gender differences in terms of detail and vividness in dream recall (Nielsen et al., 2004). Further investigation amongst an all-male sample may prove beneficial in further understanding how waking day correspondences in dreams differ between males and females.

Finally, our study method used a dream-journal method rather than in-lab dream collection with concurrent recording of EEG. Thus, we cannot characterize the stage from which dreams were recalled, and this may affect the presence or absence of dream-lag versus day-residue. For example, it has been found that emotional processing of day events correlates with frontal theta activity during REM sleep (Eichenlaub et al., 2018) and that dream-lag was present for REM dreams but not those recalled from N2 (Blagrove et al., 2011). The aforementioned studies examined only 20 participants; a 7-day EEG recording study would have proven more difficult for our empirical study because of the large number of participants (N = 45). REM dreams also represent the majority of spontaneously recalled dreams (Monroe, Rechtschaffen, Foulkes, & Jensen, 1965; Nielsen, 2000), and thus we expect our sample consistent primarily of REM dreams. However, without EEG recordings we cannot rule out the possibility that NREM dreams may in part be represented in our findings.

5. Conclusion

The day-residue effect was replicated in this study for negative emotions and neutral items but not for positive emotions. A significant dream lag effect was not observed between days 5 and 7. Due to mixed findings of the dream-lag effect in the literature, more research is warranted in examining the most accurate method of observing dream correspondences to determine under which conditions the effect is observed. A next logical step in this line of work would be a more intensive 7-day protocol with a large sample using concurrent EEG recordings comparing positive, negative, and neutral content to waking-day journals, as well as comparing judges' quantitative analyses to participants' own qualitative ratings of correspondences in their dreams.

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Appendix A:

Example of dream scoring for negative emotions:

I had a dream about my mom and I being trapped in the woods with no way out. I remember that it was very dark, I could hear my family's voices but we all turned up empty handed for an escape. I was full of ***fear*** *and at times I couldn't move.*

Scoring:
Negative emotions: 1