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All's eco-friendly that ends eco-friendly: Short-term memory effects in carbon footprint estimates of temporal item sequences

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Abstract

When people estimate the summative carbon footprint of a sequence of events, how are the individual events integrated? In three experiments, we found that summative carbon footprint judgments of item sequences are disproportionately influenced by items at the end of the sequence in comparison with those at the beginning—a recency effect. When, for example, sequences ended with a low carbon footprint item, they were assigned a lower carbon footprint than corresponding sequences with an identical content but different item order. The results also revealed that a green peak (presenting many low carbon footprint items at once) had a relatively large effect on estimates when the peak was contextually distinct from other items in terms of its valence. The results are consistent with an account within which distinctiveness of representations within short-term memory differentially influences decision-making and suggest that memory processes bias the perceived environmental footprint of temporally separated instances.

KEYWORDS

carbon footprint estimates, distinctiveness, peak-end rule, recency effect, short-term memory

1 | INTRODUCTION

Imagine that you watch an episode or a video of environmentally significant events—such as a commercial involving people's pro-environmental behavior or a news report of the events from a natural disaster—and you form an impression of the consequences of those events. In relation to the perception of the combined consequences of these events, does it matter *when* individual events take place during the episode?

Judgments of environmental impact are influenced by several systematic biases (Holmgren, Andersson, & Sörqvist, 2018; Pasca, 2022; Pasca & Poggio, 2021; Sokolova et al., 2023; Sörqvist et al., 2020). For example, while people accurately assign a higher carbon footprint to two petrol cars in comparison with one petrol car, they tend to think two hybrid cars have the same impact as one (Kim & Schuldt, 2018)—a quantity insensitivity (Kusch & Fiebelkorn, 2019); when people judge how much carbon binding is necessary to compensate for a specific amount of CO_2 emission, they tend to think more is needed when the emissions are caused by an immoral action (Sörqvist, MacCutcheon, et al., 2022)—a moral spillover; when people rate the energy intensiveness of household appliances, they tend to assign higher values to larger objects although the opposite is often more accurate (Cowen & Gatersleben, 2017)—a size heuristic; and when a meal with red meat (a relatively carbon footprint intensive food type) is combined with an organic apple (a side dish with a relatively low carbon footprint), the perceived carbon footprint of the whole meal is reduced (Gorissen & Weijters, 2016)—a negative footprint illusion (Holmgren et al., 2018, 2018).

In past research on judgments of item's environmental impact, the to-be-estimated items have all been present at the time of judgment (see Sörqvist et al., 2020, for a review). For instance, in the study by Kim and Schuldt (2018), participants made judgments of the environmental impact of cars in their immediate view at the time of judgment. However, the perceived carbon footprint of items and everyday behaviors, such as the selection of articles when shopping, or various environmentally significant behaviors carried out during the period of a week, involves more than merely processing combinations of instances of varying degrees of environmental impact. This is because items and behaviors that leave a carbon footprint are also often temporally widespread. For example, products are chosen sequentially when visiting different shopping aisles and, similarly, when selecting products in online web shops. Thus, memory should play a role in how the environmental impact of the items is perceived. Yet, these mnemonic processes have never been studied before. In the current study, we ask: when people estimate the summative carbon footprint of a sequence of events, how are the individual events integrated?

Many factors come into play when sequential and temporally extended information is integrated (Anderson, 1981; Loewenstein & Prelec, 1993). For example, there is the well-known primacy effect in person impression—the impression of a person is particularly influenced by the first as opposed to the middle and last piece of information (Sullivan, 2019). Contextual factors can reverse this into a recency effect, such as when participants are instructed to make hasty responses and are only told to make the impression formation after processing all information about the person (Richter & Kruglanski, 1998), although this appears to be relatively rare (Sullivan, 2019). Primacy and recency effects are also amongst the most robust findings in the memory literature (Deese, 1957; Ebbinghaus, 1913; Henson, 1998; Jahnke, 1965; Murdock, 1962). Memory for the first part of an episode (Li, 2009) or a list of to-be-recalled items (Ward, 2002) is often better than for the middle. Similarly, memory of the last part, and in particular for the very last item in a to-be-recalled list, is often better than for the middle part (Hughes & Marsh, 2017; Sörqvist, 2010).

Furthermore, the primacy and recency effects are influenced by stimuli modality (Penny, 1989). Recall from the primacy part of a sequence is usually greater than recall from the recency part when to-be-recalled items are visually presented, but not necessarily when the to-be-recalled items are auditorily-presented. Recency effects are typically larger in recall of word lists when the to-be-recalled items are auditorily-presented in comparison with when they are visually-presented. Although smaller in magnitude, recency effects usually manifest also with visual to-be-recalled material. They are found when the to-be-recalled items comprise visual-verbal items (e.g., digits; Sörqvist, 2010) as well as when they comprise pictures (e.g., Cohen, 1972; Manning & Schreier, 1988).

While primacy and recency effects in short-term memory are very robust, and serial position effects can be observed across different timescales—for lists presented in under a second up to months (Baddeley & Hitch, 1993)—they also have boundary conditions. For example, the primacy effect becomes smaller in magnitude when participants do not have time to rehearse the items (Jahnke, 1968; Tan & Ward, 2000). Recency effects, in turn, become larger when lists are longer, especially in free recall (Ward et al., 2010). Drawing on the primacy and recency effects in the short-term memory literature, we might expect similar order effects in carbon footprint estimates of episodes. Environmentally significant instances at the beginning and at the end of a sequence should have a disproportional influence on the perceived carbon footprint of the sequence in comparison with environmentally significant instances in the middle of the sequence. At least under the assumption that estimates are based on memory of the sequence.

Further evidence of order effects in information integration comes from retrospective evaluation of past affective episodes. Here, contrary to the case of short-term memory, recency effects appear to be stronger than primacy effects (Schreiber & Kahneman, 2000). A consistent finding in the literature on retrospective affective estimates of episodes is that those estimates are disproportionately influenced by the contents of the last part of the episode (the end) as well as the episode's moment of peak affect (Fredrickson, 2000)—the peak-end rule (see Alaybek et al., 2022, for a review). Affective evaluations of episodes have some similarities and differences to carbon footprint estimates of item sequences. One similarity between the two types of episodes/sequences is that both contain information of positive/good and negative/bad valence—affective episodes may comprise moments of positive and negative affect whereas sequences with environmentally significant items comprise instances that can be seen as good or bad for the environment (cf. Sokolova et al., 2023). From this analogy, retrospective carbon footprint estimates of item sequences might be expected to follow a similar pattern to retrospective estimates of affective episodes. Another similarity is that of duration neglect in affective estimates (Fredrickson, 2000) and quantity insensitivity in environmental impact estimates (Kim & Schuldt, 2018). The duration of episodes usually has a negligible effect on perceived affect. For example, experiencing pain for a longer duration does not have much influence on the affective evaluation of the episode (Chajut et al., 2014). Similarly, adding low carbon footprint items to a set of other low carbon footprint items seem not to change the perceived environmental impact of the items (Kim & Schuldt, 2018). From this similarity, a quantity insensitivity might be expected also in retrospective estimates of the carbon footprint of temporal item sequences.

Findings such as the peak-end rule suggest that memory plays an important role in retrospective evaluations (Aldrovandi et al., 2015; Hoffmann & Hosch, 2023; Montgomery & Unnava, 2009). Arguments against a memory-based account of retrospective evaluations have been raised (Anderson, 1981; Hastie & Park, 1986; Lichtenstein & Srull, 1987), but a consensus seems to be that memory processes play a larger role in the evaluations when people don't make on-line (continuous) evaluations during sequence presentation, such as when they are not aware of the upcoming judgment task until after experiencing the episode (Montgomery & Unnava, 2009). Yet, memory can influence retrospective evaluations even in conditions wherein on-line judgments are possible and people are aware of the upcoming judgment task (Aldrovandi et al., 2015). Because of this, we assume that judgments of the carbon footprint of item sequences will depend on memory processes.

1.1 | The distinctiveness account

Despite their early observation (Ebbinghaus, 1913), the theoretical basis of primacy and recency effects is still contested (Brown et al., 2007; Davelaar et al., 2005; Howard & Kahana, 2002; Lehman & Malmberg, 2013; Ward, 2002). In the current investigation, we are agnostic in our view of the underpinnings of the primacy and recency effects. Nevertheless, here we entertain a temporal distinctiveness account of these effects. According to the temporal distinctiveness account, time—an item's temporal position of occurrence within a list—represents a key feature of an encoded memory trace. Recovery from episodic memory generally requires spatiotemporal context—that an item occurs in a particular time and place. Time of presentation is the principal dimension upon which list items vary. If the remembered position of a target trace stands out, or is otherwise distinctive, in the context of this temporal dimension it is retrievable. Although theories differ as to why it occurs, different schedules of temporal presentation systematically affect the recall probability of list items. The relative positions of items in a shared episode are important, not the mere passage of time. Items that occupy unique or discrepant temporal positions are better remembered. As items in the beginning of a list and the items at the end of a list are more distinct, temporally, than the middle list items, distinctiveness can explain the typical primacy and recency effects in short-term memory (Bireta et al., 2018; Glenberg & Swanson, 1986; Murdock, 1960; Neath, 1993). Because of this, environmentally significant events should be more distinct when they occupy the endpoints of a sequence and consequently have a disproportional effect on retrospective sequence judgments.

On the distinctiveness account, a distinctive event violates the prevailing context in which the to-be-remembered items are presented. On one approach, the saliency, surprise, or novelty produced by the event attracts attention. The recruitment of attention towards the event results in additional processing that enhances memory. One of the most popular ways to examine distinctiveness has been via the isolation paradigm wherein a small proportion of the memoranda presented to participants differs from the other material on typically linguistic dimensions (i.e., syllable vs. digit; e.g., von Restorff, 1933). The superior memory for the “distinctive” material represents the “distinctiveness effect”. Distinctiveness has been used as an explanation for differences in the retention of to-be-remembered material (Lockhart et al., 1976). Qualitative differences in processing determine the discriminability between traces of items, which influences their retention. Distinctive processing typically leads to highly discriminable traces (Lockhart et al., 1976). A trace—the functional description of an item—is useful for retrieval to the extent that it contrasts descriptively with other items. On this view, distinctiveness is underpinned by the cognitive operation of, first, establishing a dimension of similarity within which the items are processed, and second, detecting a difference of specific items from that similarity. Items that deviate from the established similarity are processed distinctively while the processing of background items is largely confined to their similarity (Hunt, 2006; Hunt & Seta, 1984). Distinctiveness is thus relative because it requires some change against a common background along specific dimensions. In the context of carbon footprint estimates of item sequences, the valence of the items in the sequence comprises such a dimension along which the items vary. Suppose a sequentially presented list requiring an environmental judgement was comprised of red (high carbon footprint), yellow (intermediate carbon footprint) and green (low carbon footprint) items, the valence represented by the color comprises a dimension along which the items vary—thus environmental friendliness/carbon footprint, represented by color, comprises a dimension of similarity and dissimilarity.

In summary, there are at least two factors that determine items' distinctiveness in the context of carbon footprint estimates of item sequences—the temporal dimension and the environmental friendliness/carbon footprint (represented by color) dimension. Similar to recall of word lists, items presented towards the beginning and the end of the sequence are more temporally distinct than items presented during the middle. Items can also be relatively distinct on a qualitative dimension, by deviating in environmental-friendliness valence from other items in the same sequence. Items with the same carbon footprint may simply be categorized by their similarity and thus not via distinctive processing, while items that deviate from the item-context on this dimension will be processed distinctively.

1.2 | Overview of experiments

Whether order effects such as the primacy and the recency effect appear also in the context of carbon footprint estimates of temporal item sequences remains an open question. Experiment 1 set out to test the existence of order effects (primacy and recency effects) in carbon footprint estimates of item sequences. To preview the results, Experiment 1 found that environmentally significant items (high and low carbon footprint items) presented at the end of the sequence had a disproportional effect on the estimates—a recency effect—but there was no evidence of a primacy effect. Experiment 2 tested whether this would replicate when the to-be-estimated material was designed to put less emphasis on mnemonic processing of the material. While participants self-reported different strategies—a greater reliance on memory in Experiment 1 and a greater reliance on item counting in Experiment 2—the pattern of results was similar across the two experiments. After establishing and replicating a recency effect in this context, Experiment 3 expanded the inquiry to test the effects of peak and end events in the same experimental setting.

2 | EXPERIMENT 1

In Experiment 1, sequences mainly comprising items with an intermediate carbon footprint were presented to the participants. Compared to the rest of the items within the sequence, some sequences had a more environmentally significant item (relatively low or relatively high carbon footprint) presented at the beginning, at the end, or in the middle of the sequence. Evidence for order effects, in line with previous research, would be obtained if summative carbon footprint estimates of the sequence were disproportionately influenced by items in the beginning (a primacy effect) or by items at the end (a recency effect) of the sequence, in comparison with mid-sequence items. Moreover, the experiment was designed to test whether there is a quantity insensitivity (similar to episode duration neglect) in carbon footprint estimates of item sequences, in the sense that carbon footprint estimates are independent of the number of items in the sequences. If carbon footprint estimates of temporal sequences are indeed independent of item quantity, then there should be no difference between shorter (e.g., 3–5 items) and longer (e.g., 7–9 items) sequences. Experiment 1 was designed to address these two phenomena—order effects and quantity insensitivity—to characterize the basic effects before moving on to more complex experimental settings looking at both peaks and order effects.

2.1 | Methods

2.1.1 | Participants

A total of 27 Swedish speaking participants (63% women, 33% men [one participant did not respond to the gender question], mean age of 31.33 years, $SD = 10.62$; 96% Caucasian) took part in Experiment 1. None reported color-blindness or difficulty seeing the difference between red and green colors by self-report. The sample size was determined based on the theoretical assumption that a primacy and recency effect in carbon footprint estimates of item sequences have approximately the same magnitude as primacy and recency effects in memory of pictures. A recency effect in memory of picture sequences was found with the effect size of Cohen's $d_z = 1.67$ with a sample size of 15 participants in a study by Manning and Schreier (1988, Experiment 1). In their Experiment 2, they found a conceptually similar effect with an effect size of Cohen's $d_z = 1.01$, again with a sample of 15 participants. This recency effect is thus large and highly reliable. An a priori power analysis (using G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) revealed that the estimated sample size needed to detect an effect of the assumed size (Cohen's $d_z = 1.01$) is 15 participants. Our experiment uses a novel and more complex design however, perhaps with more room for error variance. We therefore decided to aim for a sample size of about 25 participants. All participants received a small honorarium for their participation. The experiments reported in this paper received research ethical clearance from the Swedish Ethical Review Authority (Dnr 2023-01109-01).

2.1.2 | Materials

Response collection and stimulus presentations were controlled by a desktop computer. Sketched pictures of houses were used for stimulus presentation (Holmgren et al., 2018). Examples are shown in Figure 1. Each picture contained 24 houses. The houses were randomly distributed across a 9 × 8 matrix, with the constraint that 3 houses were presented on each row of the matrix. Each picture contained either red (high carbon footprint) or yellow (average carbon footprint) or green (low carbon footprint) houses. Moreover, a total of 9 pictures were created with only yellow houses (each with a different random distribution of the items in the matrix), and 3 pictures with green houses only and 3 pictures with red houses only were created in the same way as the pictures with yellow houses only. Using these pictures, a total of 7 categories of sequences were created: (1) control sequences comprising yellow houses only; (2) green primacy sequences comprising a picture with green houses in the first position followed by pictures with yellow houses; (3) green middle sequences comprising a picture with green houses in the sequence's middle position, preceded and followed by yellow houses; (4) green recency sequences with a picture with green houses at the last position preceded by yellow houses; (5) red primacy sequences comprising a picture with red houses in the first position followed by yellow houses; (6) red middle sequences comprising a picture with red houses in the sequence's middle position, preceded and followed by yellow houses; and (7) red recency sequences with a picture with red houses at the last position preceded by yellow houses. Moreover, each type of sequence was created in four different lengths. The sequences were either 3 items/pictures, 5 items/pictures, 7 items/pictures or 9 items/pictures long. Thus, 28 sequence types (7 categories, each of 4 different lengths) were created. Furthermore, each of the 28 sequences were created in three versions, for a total of 84 sequences. For each picture presentation, one of the pictures from the picture pool was randomly selected for presentation. There was no repetition of the same picture within the same sequence.

2.1.3 | Design and procedure

All participants sat alone in front of a desktop computer during the data collection. They began by reading about the general purpose of the study, filled in a consent form, and answered demographic questions. Thereafter followed the task instructions. They were told that they would see houses of different colors (yellow, red, and green), representing different energy classifications. They were told that red represents a house that generates the most kg CO_2, green the least and yellow in the middle between the other two. They were also shown an illustration of the relative classification of houses in different colors (including 7 colors, ranging from dark red to red, orange, yellow, light green, green, and dark green). Finally, they were told about the task to make estimates of sequences of these houses, how many trials they would be requested to undertake, how much time they were allowed to make each estimate, that there was no

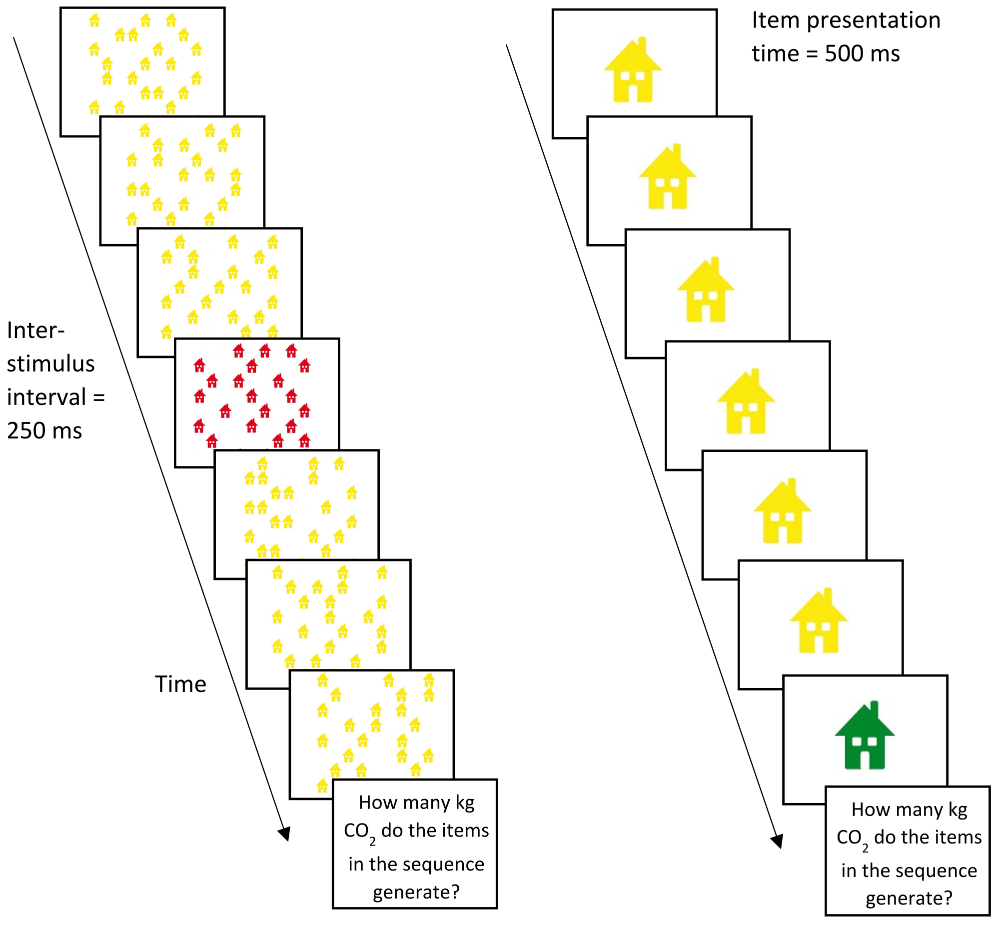

FIGURE 1 The figure shows two examples of the stimuli and sequences used in the experiments. The sequence to the left represents those of Experiment 1 and the sequence to the right those of Experiment 2. The sequences depicted are 7 pictures long, whereas in the experiments they could be either 3, 5, 7 or 9 pictures long.

necessarily accurate estimate, and that they should try to make as quick and accurate estimates as possible.

The experiment comprised a total of 88 trials. Each trial began with the word "READY – sequence N" presented in black font at the center of the computer screen, at the position where the pictures of the sequence were going to be presented, followed by the first item in the sequence. The "N" was replaced by a number, increasing arithmetically from 1 to 88, to let the participants orient themselves within the trial sequence. At stimulus presentation, the inter-stimulus interval was set to 250 ms and each item was presented for 500 ms. An answer box appeared on the computer screen at the end of each trial, immediately after the final item in the sequence, and the participants were asked to make their estimate of the carbon footprint of the items in the most recently seen sequence by typing on the computer keyboard. The participants were asked specifically to estimate how many kg CO_2 the houses generate by making an estimate between 1 kg CO_2 and 100 kg CO_2. After typing in the estimate, they were told to press a button to proceed to the next trial. If participants did not press the button, the computer automatically proceeded to the next trial after 10 s.

The first 4 trials comprised control sequences with yellow houses only, 1 of each list length. These trials were treated as warmup trials and the responses for these were removed from the analyses. After the warmup block, another 3 blocks of trials were presented. Each block comprised 28 trials, one for each of the 28 types of sequences, for a total of 84 experimental trials. Thus, each participant made 3 estimates of each type of sequence. The blocks had a self-paced pause between them, to allow participants to take a break. The sequence types were presented in a random order which was different in the three blocks, but identical for all participants. Thus, the experiment comprised a 7(list category) × 4(list length) factorial within-participants design with kg CO_2 estimates as dependent variable.

After the final block, participants were asked which strategy they used to complete the task: (1) a mnemonic strategy of trying to remember the houses, (2) a counting strategy of trying to count the houses as they appeared, (3) a combination of the mnemonic and counting strategy, or (4) another (unidentified) strategy.

2.1.4 | Data analysis and availability

Means across the three estimates of each sequence type were calculated, to obtain one measure of each of the 28 sequence types for each participant. This treatment was used to increase the reliability of the measures. The means were thereafter used as the observations in the analyses. Of the 2268 trials in total, the participants failed to make an estimate on 17 trials (0.7%). These missing values were replaced by the average value of the same participants' estimates of the other

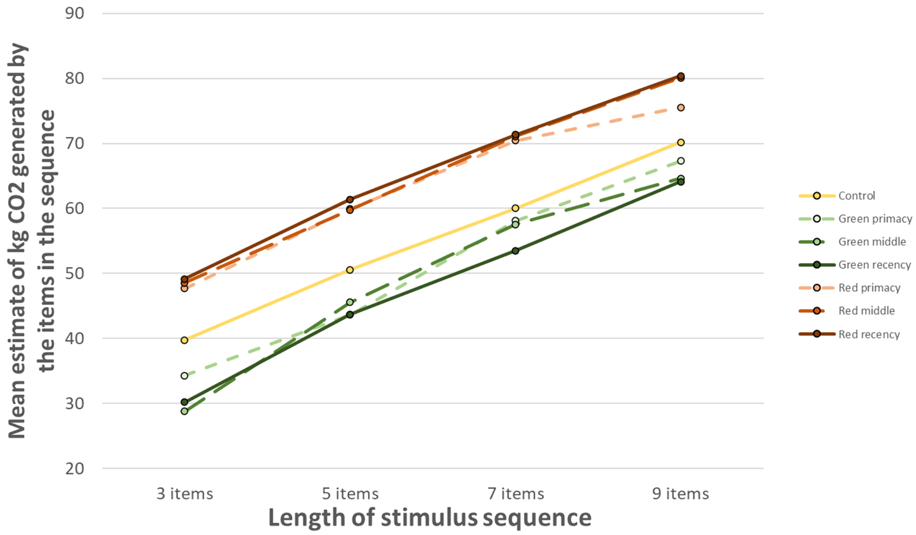

FIGURE 2 The figure shows the mean carbon footprint estimates for the sequences in Experiment 1. There were 7 sequence categories: sequences comprising only (yellow) houses with an intermediate energy efficiency (control sequences), sequences with multiple energy efficient "green" house presented first (primacy), in the middle, or last (recency) in the sequence of otherwise yellow houses, and sequences with multiple energy inefficient "red" house presented first (primacy), in the middle, or last (recency) in the sequence of otherwise yellow houses. Each sequence category had 4 different lengths. Thus, there were 28 sequence types in total. All pictures/items in Experiment 1 contained 24 houses randomly distributed across a 9 × 8 matrix.

sequences of the same sort (in other words, the observations that entered the analysis were based on two obtained estimates rather than three in 0.7% of the cases). The data across all experiments reported in this paper are available at https://doi.org/10.17605/OSF.IO/J7YRZ. The frequentist analyses were conducted using IBM SPSS Statistics version 27 and the Bayesian analyses were conducted using Jeffreys's Amazing Statistics Program (JASP). Bayesian factors concern effects that compare models that contain the effect to equivalent models stripped of the effect. Bayes Factors (BF) with the 10-subscript (BF_{10}) represent the strength of the evidence in favor of the hypothesis over the null-hypothesis. BF_{10} values between 3 and 10 are conventionally treated as evidence in favor of the hypothesis, values above 10 are conventionally regarded as strong evidence in favor of the hypothesis, and values between 1 and 3 as anecdotal evidence in favor of the hypothesis over the null-hypothesis. Values under 1 are regarded as no evidence for the hypothesis. We defined the strength of evidence based on the categorization scheme produced by Jeffreys (1961) and updated by Lee and Wagenmakers (2013).

2.2 | Results and discussion

Figure 2 shows the grand mean estimates of each type of sequence in Experiment 1. Participants consistently assigned a higher value to sequences containing a carbon-intensive red item and a lower value to sequences with a low-carbon green item. A 4(list length: 3, 5, 7 and 9 items) × 7(list category) repeated measures analysis of variance with kg CO_2 estimates as dependent variable revealed a significant effect of list length, $F(3, 78) = 91.20$, $p < .001$, $\eta_p^2 = .78$, $BF_{10} = 2.24 \times 10^{22}$, and list type, $F(6, 156) = 76.71$, $p < .001$, $\eta_p^2 = .75$, $BF_{10} = 5.62 \times 10^{40}$, and an interaction between the factors, $F(18, 468) = 2.43$, $p < .001$, $\eta_p^2 = .09$, $BF_{10} = 10.45$.

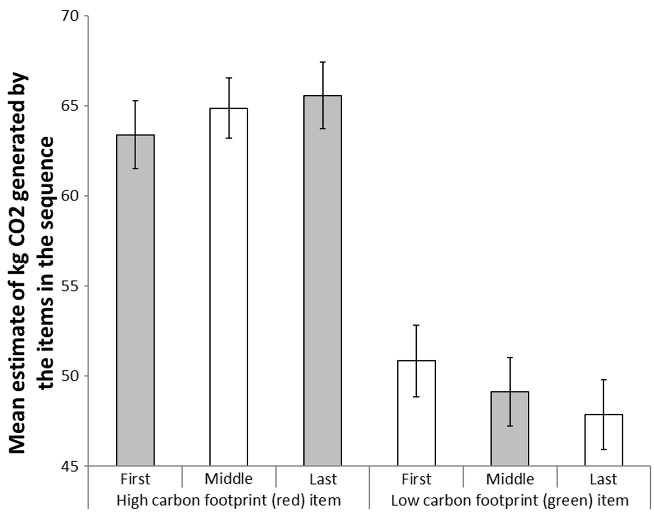

FIGURE 3 The figure shows the mean carbon footprint estimates for sequences with multiple energy efficient "green" houses or multiple energy inefficient red houses presented first (primacy), in the middle, or last (recency) in the sequence of otherwise yellow (intermediate energy efficiency) houses in Experiment 1. All pictures in Experiment 1 contained 24 houses randomly distributed across a 9 × 8 matrix. Error bars represent standard error of means.

To take a closer look at this interaction, the grand means of the green and red list types across the three positions (primacy, middle, recency) were calculated (Figure 3). A 2(list category: green vs. red) × 3(position) repeated measures analysis of variance with these grand

TABLE 1 The portion of participants' self-reported strategies to complete the task in each experiment.

	Self-reported strategy			
	Mnemonic	Counting	Mnemonic and counting combined	Other
Experiment 1	19%	0%	78%	3%
Experiment 2	6%	39%	53%	2%
Experiment 3	16%	25%	52%	7%

means as dependent variable revealed a significant effect of list type, $F(7, 156) = 122.42$, $p < .001$, $\eta_p^2 = .83$, $BF_{10} = 3.46 \times 10^8$, no effect of position, $F(2, 52) = 0.51$, $p = .605$, $\eta_p^2 = .02$, $BF_{10} = 0.10$, but a significant interaction between the two factors, $F(2, 52) = 10.56$, $p < .001$, $\eta_p^2 = .29$, $BF_{10} = 8436.17$. Follow-up t-tests revealed that mean estimates for green recency lists were significantly lower than for green middle lists ($M_{diff} = 1.27$, $SE = 0.53$), $t(26) = 2.39$, $p = .024$, 95% CI [0.18–2.36], $BF_{10} = 2.26$, Cohen's $d = 0.46$, and green primacy lists ($M_{diff} = 2.98$, $SE = 0.89$), $t(26) = 3.31$, $p = .003$, 95% CI [1.13–4.82], $BF_{10} = 14.17$, Cohen's $d = 0.64$. The difference between green middle and green primacy lists was also significant ($M_{diff} = 1.71$, $SE = 0.78$), $t(26) = 2.18$, $p = .038$, 95% CI [0.10–3.31], $BF_{10} = 1.54$, Cohen's $d = 0.42$. Moreover, mean estimates of red recency lists were significantly higher than for red primacy lists ($M_{diff} = 2.18$, $SE = 0.70$), $t(26) = 3.11$, $p = .005$, 95% CI [0.74–3.62], $BF_{10} = 9.15$, Cohen's $d = 0.60$, but they did not differ from estimates of red middle lists ($M_{diff} = 0.70$, $SE = 0.49$), $t(26) = 1.42$, $p = .168$, 95% CI [0.32–1.72], $BF_{10} = 0.50$, Cohen's $d = 0.27$. Mean estimates of red middle lists were also significantly higher than estimates of red primacy lists ($M_{diff} = 1.47$, $SE = 0.69$), $t(26) = 2.11$, $p = .044$, 95% CI [0.04–2.90], $BF_{10} = 1.37$, Cohen's $d = 0.41$.

Taken together, Experiment 1 revealed that CO_2-high and CO_2-low items have a larger effect when presented at recency (for green and red items) than when presented at primacy on the overall carbon footprint estimate of the items in the sequence. The effect of the environmentally significant item appears to be progressively stronger, the closer to the end of the sequence it is presented, suggesting that its effect declines as a function of its availability in memory. Moreover, sequence length was a strong determinant of carbon footprint estimates. Thus, in this sense, there was no evidence for a quantity insensitivity (or duration neglect).

3 | EXPERIMENT 2

Since each picture in the sequences in Experiment 1 contained multiple stimuli, this feature might have promoted a mnemonic strategy whereby participants made their estimate based on mnemonic record the most recent sequence. Indeed, most participants in Experiment 1 reported using a mnemonic strategy (19%) or a combination of a counting and a mnemonic strategy (78%), while none (0%) reported using a pure counting strategy (Table 1). Given the debate on the role of memory processes in retrospective evaluations (Aldrovandi et al., 2015; Anderson, 1981; Hastie & Park, 1986; Hoffmann & Hosch, 2023; Lichtenstein & Srull, 1987; Montgomery & Unnava, 2009), and since the recency effect in environmental impact estimates of item sequences is a novel finding in a novel experimental paradigm, it would be useful to establish the reliability of the effect in a conceptual replication. Experiment 2 hence served two purposes: First, it aimed to test if the recency effects found in Experiment 1 could be replicated with a slightly different stimulus material. Second, Experiment 2 aimed to test if recency effects of similar magnitude are obtained when each picture in the sequence contains a single item. With a single item in each picture, it should be easy for the participants to count all items/houses continuously during stimulus presentation. Thus, participants could arguably adopt a strategy that relies less on memory processes. With a memory-based strategy, participants could try to remember the items in the sequence without continuous counting of individual items/houses and base the subsequent carbon footprint estimate on the memory trace of the sequence. With a counting-based strategy, participants could instead perform a continuous counting process by adding each new item/house to a running count in working memory and to base the subsequent carbon footprint estimate on the sum of the count. Experiment 2 addressed whether this shift in strategy influences the presence of the recency effect.

3.1 | Methods

3.1.1 | Participants

A total of 54 participants took part in Experiment 2. All participants gave their informed consent to take part in the study. None reported color-blindness by self-report, however three participants reported difficulty seeing the difference between green and red colors and were therefore removed prior to the analysis. The final sample of 51 Swedish speaking participants (69% women, 28% men; one participant identified as non-binary and one participant did not respond to the gender question; 82% Caucasian) had a mean age of 32.33 years ($SD = 14.59$). None of the participants took part in Experiment 1. A power analysis using G*Power (Faul et al., 2007) revealed an a priori requirement of 34 participants to detect the recency effect (the difference between estimates of green recency and green primacy sequences, Cohen's $d = 0.64$) found in Experiment 1. We therefore decided to aim for a sample size of over 40 participants.

3.1.2 | Materials, design and procedure

The materials, the design and the procedure were identical to those in Experiment 1 with the following exceptions. Pictures comprising a

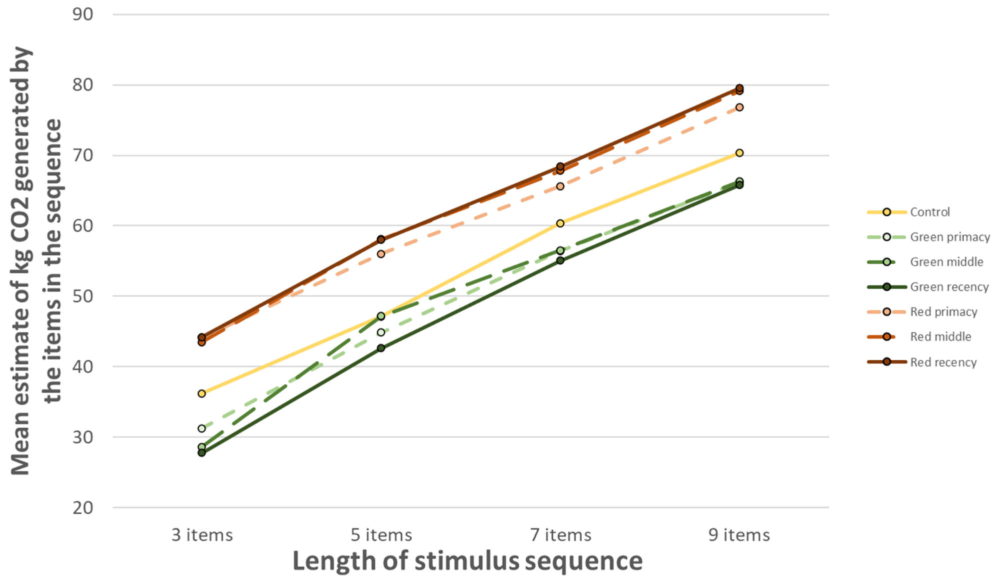

FIGURE 4 The figure shows the mean carbon footprint estimates for the sequences in Experiment 2. There were 7 sequence categories: sequences comprising only (yellow) houses with an intermediate energy efficiency (control sequences), sequences with one energy efficient "green" house presented first (primacy), in the middle, or last (recency) in the sequence of otherwise yellow houses, and sequences with one energy inefficient "red" house presented first (primacy), in the middle, or last (recency) in the sequence of otherwise yellow houses. Each sequence category had 4 different lengths. Thus, there were 28 sequence types in total. All pictures/items in Experiment 2 contained one single house.

single sketched house were created, one with a red house (high carbon footprint item), one with a yellow house (intermediate carbon footprint item) and one with a green house (low carbon footprint item). As in Experiment 1, a total of 28 sequences (7 different categories and 4 lengths of each) were created with these pictures (see Figure 1 for example).

As in Experiment 1, means across the three estimates of each sequence type were calculated, to obtain one measure of each of the 28 sequence types for each participant. This treatment was used to increase the reliability of the measures. These means were thereafter used as the observations in the analyses. Of the 4284 trials in total, the participants failed to make an estimate on 30 trials (0.7%). These missing values were replaced by the average value of the same participants' estimates of the other sequences of the same sort (in other words, the observations that entered the analysis were based on two obtained estimates rather than three in 0.7% of the cases).

3.2 | Results and discussion

Figure 4 shows the grand mean estimates of each type of sequence. Participants consistently assigned a higher value to sequences containing a carbon-intensive red item and a lower value to sequences with a low-carbon green item. A 4(list length: 3, 5, 7 and 9 items) × 7 (list type) repeated measures analysis of variance with kg CO_2 estimates as the dependent variable revealed a significant effect of list length, $F(3, 150) = 192.08$, $p < .001$, $\eta_p^2 = .79$, $BF_{10} = 6.23 \times 10^{47}$, of list type, $F(6, 300) = 137.91$, $p < .001$, $\eta_p^2 = .73$, $BF_{10} = 9.89 \times 10^{78}$, and an interaction between the factors, $F(18, 900) = 1.99$, $p = .008$, $\eta_p^2 = .04$, $BF_{10} = 0.38$, although the Bayesian factor for the interaction was notably low.

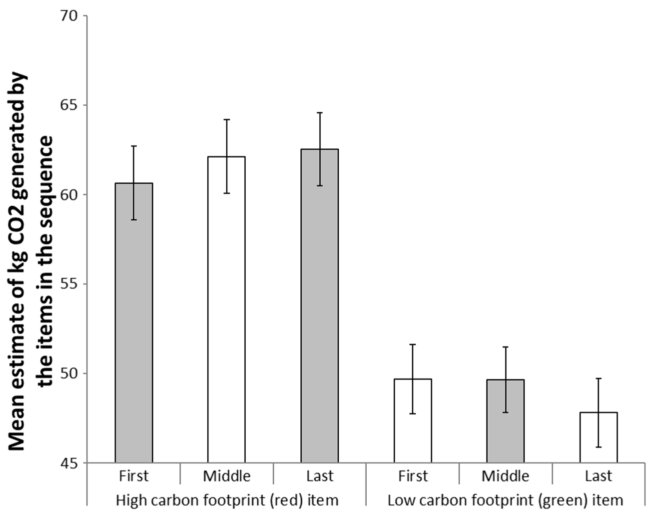

FIGURE 5 The figure shows the mean carbon footprint estimates for sequences with one energy efficient "green" house or one energy inefficient red house presented first (primacy), in the middle, or last (recency) in the sequence of otherwise yellow (intermediate energy efficiency) houses in Experiment 2. Error bars represent standard error of means.

To look more specifically at the presence of primacy and recency effects, the grand means of the green and red list types across the three positions (primacy, middle, recency) were calculated (Figure 5).

A 2(list type: green vs. red) × 3(position) repeated measures analysis of variance with these grand means as the dependent variable revealed a significant effect of list type, $F(1, 50) = 299.74$, $p < .001$, $\eta_p^2 = .86$, $BF_{10} = 6.32 \times 10^{19}$, no effect of position, $F(2, 100) = 1.44$, $p = .241$, $\eta_p^2 = .03$, $BF_{10} = 0.17$, but a significant interaction between the two factors, $F(2, 100) = 12.63$, $p < .001$, $\eta_p^2 = .20$, $BF_{10} = 2192.41$. Follow-up t-tests revealed that mean estimates for green recency lists were significantly lower than for green middle lists ($M_{diff} = 1.84$, $SE = 0.57$), $t(50) = 3.21$, $p = .002$, 95% CI [0.69–2.99], $BF_{10} = 13.30$, Cohen's $d = 0.45$, and green primacy lists ($M_{diff} = 1.88$, $SE = 0.67$), $t(50) = 2.81$, $p = .007$, 95% CI [0.54–3.23], $BF_{10} = 5.03$, Cohen's $d = 0.39$, while the difference between green primacy and green middle lists was exceptionally small and not significant ($M_{diff} = 0.04$, $SE = 0.63$), $t(50) = 0.06$, $p = .953$, 95% CI [−1.24–1.31], $BF_{10} = 0.15$, Cohen's $d = 0.01$. Moreover, mean estimates of red recency lists were significantly higher than for red primacy lists ($M_{diff} = 1.89$, $SE = 0.71$), $t(50) = 2.66$, $p = .010$, 95% CI [0.46–3.31], $BF_{10} = 3.59$, Cohen's $d = 0.37$, but they did not differ from estimates of red middle lists ($M_{diff} = 0.40$, $SE = 0.51$), $t(50) = 0.79$, $p = .434$, 95% CI [−1.43–0.62], $BF_{10} = 0.21$, Cohen's $d = 0.11$. Mean estimates of red middle lists were also significantly higher than estimates of red primacy lists ($M_{diff} = 1.48$, $SE = 0.59$), $t(50) = 2.48$, $p = .016$, 95% CI [−0.28–2.68], $BF_{10} = 2.45$, Cohen's $d = 0.35$.

Taken together, Experiment 2 also revealed a recency effect in retrospective carbon footprint estimates of item sequences, such that environmentally significant items have a larger effect if they appear at the end of the sequence. Again, there was some evidence suggesting that the effect of the environmentally significant item becomes progressively stronger, the closer to the end of the sequence it is presented. In this experiment, this pattern emerged for the red items, while there was no difference between green primacy and green middle sequences. It is unclear why this change in pattern emerged. One possibility is that the emphasis on the counting strategy strengthened the effect of the primacy item (at least for green items), but still there was no evidence of a primacy effect in Experiment 2. Moreover, there was, as in Experiment 1, no evidence of quantity insensitivity.

4 | CROSS-EXPERIMENT ANALYSIS

In comparison with Experiment 2, a relatively large portion of participants (19%) reported using a pure mnemonic strategy to complete the task in Experiment 1, while also a large portion (78%) reported using a combination of a mnemonic strategy and a counting strategy in Experiment 1. A single participant reported using another unspecified strategy. Notably, none of the participants in Experiment 1 reported a pure counting strategy, in contrast to Experiment 2 where 39% said they used this strategy (Table 1). The shift in strategy deployment motivated a cross-experiment analysis to test whether the recency effect differs in magnitude across the two experiments.

A 2(list category: green vs. red) × 3(position) × 2(experiment) repeated measures analysis of variance with kg CO_2 estimates as dependent variable was calculated. The analyses revealed a main effect of list category, $F(1, 76) = 387.52$, $p < .001$, $\eta_p^2 = .84$, $BF_{10} = 1.79 \times 10^{29}$, and a significant interaction between list category and position, $F(2, 152) = 22.75$, $p < .001$, $\eta_p^2 = .23$, $BF_{10} = 4.79 \times 10^7$, but there was no significant main effect of position, $F(2, 152) = 0.94$, $p = .394$, $\eta_p^2 = .01$, $BF_{10} = 0.06$, no significant main effect of experiment, $F(1, 76) = 0.28$, $p = .559$, $\eta_p^2 = .004$, $BF_{10} = 2.14$, no significant interaction between position and experiment, $F(2, 152) = 0.65$, $p = .525$, $\eta_p^2 = .01$, $BF_{10} = 0.02$, and no significant three-way interaction between factors, $F(2, 152) = 0.90$, $p = .408$, $\eta_p^2 = .01$, $BF_{10} = 0.14$. The Bayesian factors provide substantial evidence for the conclusion that the response patterns—and the recency effects specifically—are similar across the two experiments, even though participants differed in their self-reported strategies.

In addition to the analyses above, another set of analyses were conducted using self-reported strategy as an independent variable in the analyses. The purpose of these analyses was to further explore whether strategy could modulate the order effects. These analyses revealed no additional information that would suggest that strategy has such an effect. Strategy did not significantly interact with sequence type, sequence position or the combination of the two.

In sum, Experiments 1 and 2 demonstrated and replicated a recency effect in carbon footprint estimates of temporal item sequences regardless of whether participants relied more heavily on a counting strategy or adopted a strategy that involved mnemonic processes. It seems therefore as the enhanced temporal distinctiveness associated with the sequence ending interacts with the distinctive processing and produces a disproportional influence on subsequent decision-making, regardless of the cognitive strategy employed to complete the task.

5 | EXPERIMENT 3

In Experiment 3, sequences with high (red), low (green) and intermediate/neutral (yellow) items were included to test a series of predictions. A strong interpretation of the peak-end rule is that it would predict that estimates of sequences comprising yellow items but with a green peak (multiple low carbon footprint items presented at once) and a green end, should not differ from estimates of corresponding sequences comprising a green peak and end but with both yellow and red items. This is because the peak and the end should determine retrospective evaluations while the rest of the sequence is largely neglected.

A milder version of the peak-end rule would predict that estimates are disproportionately influenced by the end and by the peak of the sequences, but other items also matter. Furthermore, in view of the distinctiveness principles of the effects of peaks on retrospective evaluations of episodes (Ariely & Carmon, 2000), peaks might have a stronger effect when they stand out from the surrounding context. There are at least two ways by which an environmentally significant peak can differentiate from its

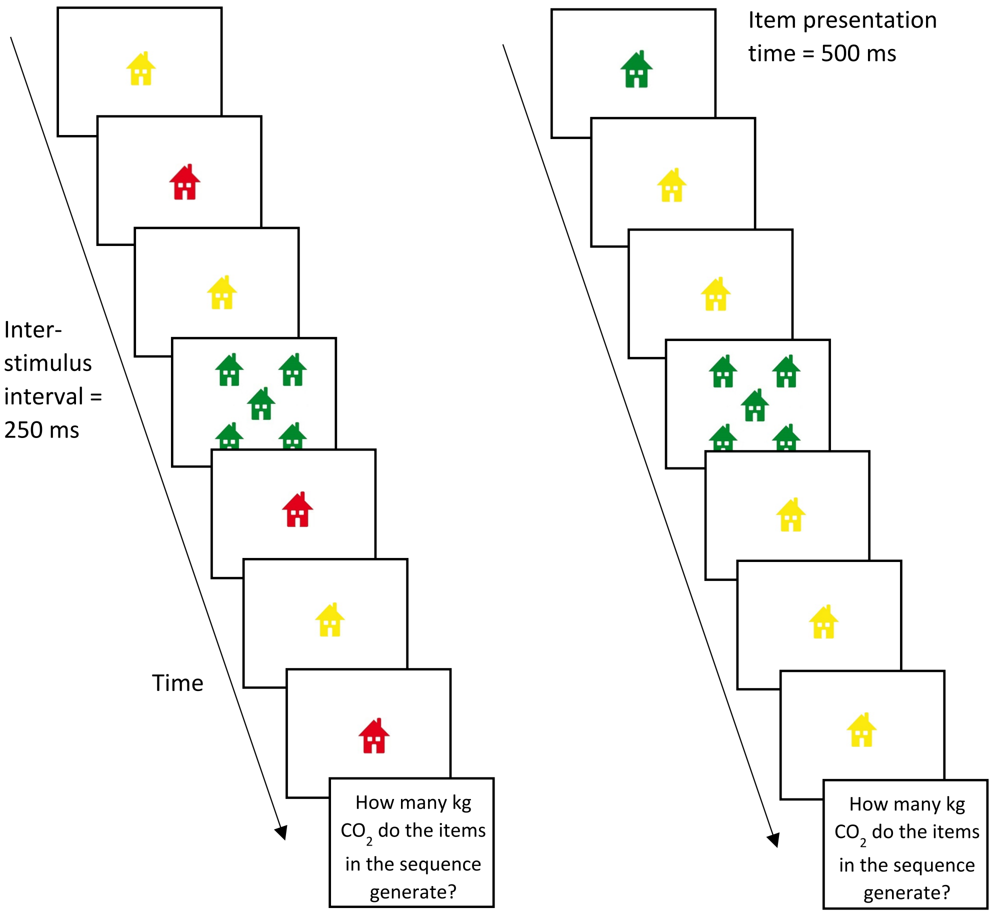

FIGURE 6 The figure shows two examples of the stimuli and sequences used in Experiment 3. The sequence to the left represents a "peak-blend sequence" and the sequence to the right represents a "peak-primacy sequence". The sequences depicted are 7 pictures long, whereas in Experiment 3 they could be either 5, 7 or 9 pictures long.

surrounding context: By its physical properties and by its valence/environmental significance. Regarding its physical properties, a peak comprising multiple green items might have a larger effect in the context of a sequence comprising yellow (intermediate) items only, in comparison with its effect in a context of both yellow and red items, because it is differentiated more by its unique physical properties—a distinctiveness-by-physical properties hypothesis.

Concerning affective episodes, peak events represent events with high affective strength in comparison with other events in the same episode (Fredrickson, 2000). An analogy in the context of items with various carbon footprint would be that peaks represent events that differ greatly in environmental significance from other items in the same sequence. Regarding its valence then, a peak comprising multiple green items might have a larger effect in the context of a sequence comprising yellow and red items, in comparison with its effect in a context of only yellow items, because it is differentiated more from the red items in terms of its degree of valence. If so, carbon footprint estimates of sequences comprising yellow items, red items and green peaks should be lower than of sequences comprising yellow and red items without the green peaks, whereas there should be a smaller difference between carbon footprint estimates of sequences comprising yellow items and green peaks and sequences comprising yellow items only—a distinctiveness-by-valence hypothesis.

5.1 | Methods

5.1.1 | Participants

As in Experiment 2, we aimed for a sample size of over 40 participants based on the a priori power analysis of the results from Experiment 1. A total of 44 Swedish speaking participants (68% women, 27% men, 2% identified as non-binary [1 participant did not respond to the gender question], mean age of 39.23 years, $SD = 15.85$; 98% Caucasian) took part in Experiment 3. None of them took part in Experiments 1 or 2. All participants gave their informed consent to take part in the study and received a small honorarium for their participation. No participant self-reported color blindness and all were able to see the difference between green and red colors.

5.1.2 | Materials, design, and procedure

The materials, the design and the procedure were identical to those in Experiment 2 with the following exceptions. A picture with five green houses was created. This stimulus is henceforth called a peak. Twelve list categories were created (see Figure 6 for examples): lists with yellow houses but with a green peak in the middle and a single green house as the last item in the list (peak-recency list); list with an even number of yellow and red items randomly distributed across the

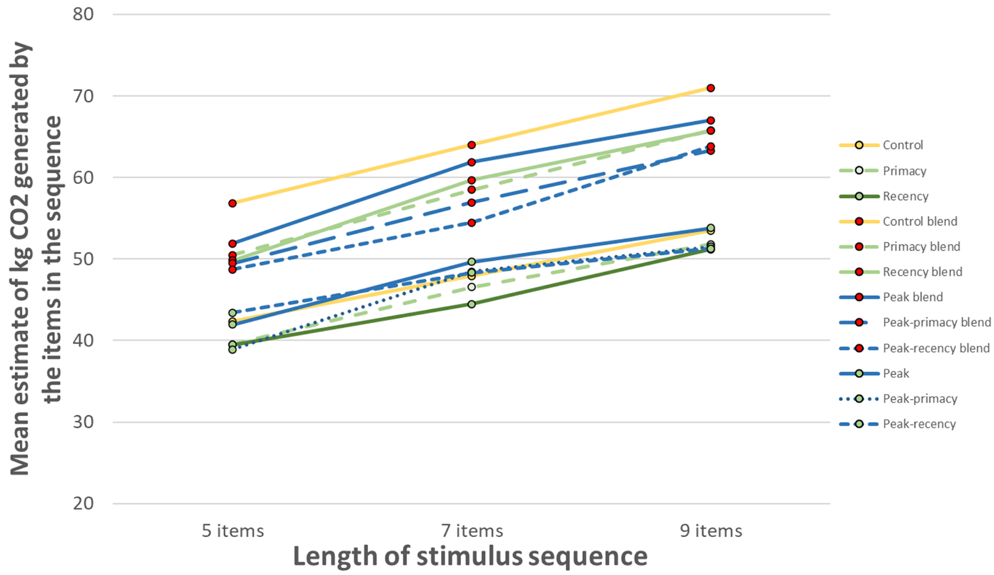

FIGURE 7 The figure shows the mean carbon footprint estimates for the 12 sequence types across 3 list lengths (36 sequence types in total) in Experiment 3.

sequence but with a green peak in the middle and a single green house at the end (peak-recency blended list); lists with yellow houses but with a green peak in the middle and a single green house as the first item in the list (peak-primacy list); list with an even number of yellow and red items randomly distributed across the sequence but with a green peak in the middle and a single green house as the first item in the list (peak-primacy blended list); lists with yellow houses but with a green peak in the middle (peak list); list with an even number of yellow and red items randomly distributed across the sequence but with a green peak in the middle (peak blended list); lists with yellow houses but with a single green house as the last item in the list (recency list); list with an even number of yellow and red items randomly distributed across the sequence but with a single green house at the end (recency blended list); lists with yellow houses but with a single green house as the first item in the list (primacy list); list with an even number of yellow and red items randomly distributed across the sequence but with a single green house at the beginning (primacy blended list); lists with only yellow houses (control lists); and, finally, lists with an even number of yellow and red houses randomly distributed across the sequence (control blend lists).

Each of the 12 sequence categories was created with three different lengths. They could either be 5, 7 or 9 items long. Hence, there was a total of 36 sequence types. The first 3 trials of the experiment comprised control sequences with yellow houses only, 1 of each list length. These trials were treated as warmup trials and the responses for these were removed from the analyses. After the warmup block, another 3 blocks of trials were presented. Each block comprised 36 trials, one for each of the 36 types of sequences. Thus, each participant made 3 estimates of each type of sequence, for a total of 108 experimental trials.

As in previous experiments, means across the three estimates of each sequence type were calculated, to obtain one measure of each of the 36 sequence types for each participant. These means were thereafter used as the observations in the analyses. Of the 4752 trials in total, the participants failed to make an estimate on 36 trials (0.8%). These missing values were replaced by the average value of the same participants' estimates of the other sequences of the same sort (in other words, the observations that entered the analysis were based on two obtained estimates rather than three in 0.8% of the cases).

5.2 | Results and discussion

Figure 7 shows the grand mean estimates of each type of sequence. A 3(list length: 5, 7 and 9 items) × 12(list type) repeated measures analysis of variance with kg CO_2 estimates as dependent variable revealed a significant effect of list length, $F(2, 86) = 83.41$, $p < .001$, $\eta_p^2 = .66$, $BF_{10} = 7.41 \times 10^{17}$, of list type, $F(11, 473) = 69.31$, $p < .001$, $\eta_p^2 = .62$, $BF_{10} = 5.27 \times 10^{87}$, and an interaction between the factors, $F(22, 946) = 2.96$, $p < .001$, $\eta_p^2 = .06$, $BF_{10} = 663.96$.

Figure 8 shows the grand means of the 12 sequence types. A first thing to note was that grand mean estimates were lower for sequences comprising yellow items and a green item at the end, than for sequences comprising yellow items and a green item at the beginning ($M_{diff} = 0.92$, $SD = 2.86$), $t(43) = 2.12$, $p = .040$, 95% CI [0.04–1.79], $BF_{10} = 1.24$, Cohen's $d = 0.32$. Thus, the standard recency effect was replicated in Experiment 3. The Bayes factor was small, but the effect corroborates the recency effects found in Experiments 1 and 2 and adds to the effect's replicability and reliability. When the sequences with green endpoints (without peaks) comprised both yellow and red items, however, this difference was not obtained ($M_{diff} = 0.18$, $SD = 5.11$), $t(43) = 0.23$, $p = .818$, 95% CI [−1.73–1.37], $BF_{10} = 0.17$, Cohen's $d = 0.04$. Hence, the presence of environmentally significant, negative, items negated the disproportionately positive effect from a green recency.

The second thing to note was that grand mean estimates for sequences comprising yellow items, a green peak and recency, were significantly lower than for corresponding sequences that also contained red items ($M_{diff} = 8.02$, $SD = 6.24$), $t(43) = 8.52$, $p < .001$, 95% CI [6.12–9.91], $BF_{10} = 1.13 \times 10^8$, Cohen's $d = 1.28$. The pattern was

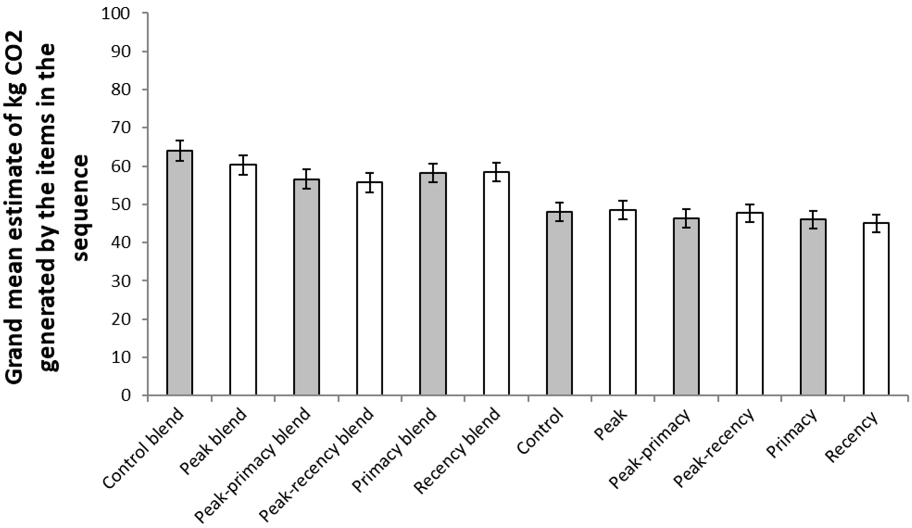

FIGURE 8 The figure shows the grand means of carbon footprint estimates for all 12 sequences in Experiment 3. Error bars represent standard error of means.

similar for the comparison between sequences comprising a green peak and primacy and for corresponding sequences that also contained red items ($M_{diff} = 10.28$, $SD = 7.21$), $t(43) = 9.46$, $p < .001$, 95% CI [8.09–12.47], $BF_{10} = 1.98 \times 10^9$, Cohen's $d = 1.43$. Evidently, then, a green peak and endpoint did not negate the effects of environmentally significant, negative, stimuli in the sequence. The resulting pattern is thus inconsistent with a strong interpretation of the peak-end rule wherein carbon footprint estimates are only determined by the peak and the end of the sequence whereas other items are neglected.

A third thing to note is that a green peak had a larger neglecting effect when it was presented in the context of yellow and red items in comparison with the context of yellow items only. A 2(list type: with green peak vs. without green peak) × 2(list type: with yellow and red standard items vs. with yellow standards only) repeated measures analysis of variance with kg CO_2 estimates as the dependent variable revealed a significant effect of list type, $F(1, 43) = 171.68$, $p < .001$, $\eta_p^2 = .80$, $BF_{10} = 6.64 \times 10^{13}$. The main effect of peak was not significant, $F(1, 43) = 2.87$, $p = .098$, $\eta_p^2 = .06$, $BF_{10} = 0.76$, but the interaction between the two factors was, $F(1, 43) = 13.75$, $p < .001$, $\eta_p^2 = .24$, $BF_{10} = 39.96$. Grand mean estimates of sequences comprising yellow items with a green peak in the middle were slightly higher than estimates of control sequences with yellow items only ($M_{diff} = 0.55$, $SD = 7.74$). This difference was not significant, $t(43) = 0.47$, $p = .642$, 95% CI [−1.81–2.89], $BF_{10} = 0.18$, Cohen's $d = 0.07$. In contrast, estimates of sequences with yellow and red items and a green peak in the middle were significantly lower than for corresponding sequences without the green peak in the middle ($M_{diff} = 3.67$, $SD = 6.62$), $t(43) = 3.68$, $p < .001$, 95% CI [1.66–5.69], $BF_{10} = 44.34$, Cohen's $d = 0.56$. This suggests that a green peak has a large negating effect of the presence of environmentally significant, negative, items, while it does not have the same effect in the context of more environmentally neutral items. Taken together, the results of Experiment 3 are consistent with a milder interpretation of the peak-end rule by which the peak and end have a disproportionate influence on carbon footprint estimates. The effect of the peak is qualified by its degree of difference from other sequence-items in terms of its environment-friendliness valence. A large distinctiveness-by-valence (rather than a distinctiveness-by-physical properties) increases its negating effect on more environmentally harmful items.

6 | GENERAL DISCUSSION

The series of experiments revealed three main findings: First, retrospective carbon footprint estimates of temporal item sequences were disproportionately determined by environmentally significant (high and low carbon footprint) items appearing at the end of the sequence, in comparison with environmentally significant items appearing earlier in the sequence (Experiments 1, 2 and 3). This recency effect was similar in magnitude regardless of whether participants self-reported relying more on a mnemonic strategy (Experiment 1) or a counting strategy (Experiment 2). Second, green peaks (presenting many low carbon footprint items at once) in the context of sequences comprising environmentally harmful (red, high carbon footprint items) and environmentally neutral (yellow, intermediate carbon footprint) items produced a significant downshift in the carbon footprint estimates, to a larger degree than green peaks presented in the context of environmentally neutral items only (Experiment 3). Finally, third, the number of items in the sequences—and hence their length—has a clear effect on the carbon footprint estimates, such that more items are associated with a larger carbon footprint estimate. Hence, there was no evidence of quantity insensitivity (or duration neglect).

6.1 | Theoretical implications

6.1.1 | Functional similarities and dissimilarities between carbon footprint estimates of item sequence and other phenomena

The absence of a primacy effect suggests functional dissimilarities with short-term serial recall wherein both primacy and recency effects are typically observed, often with stronger primacy than recency effects (e.g., Henson, 1998; Hughes & Marsh, 2017; Macken et al., 2016; Sörqvist, 2010). One possible explanation of the absence of a primacy effect in the current series is the rapid stimulus presentation time. In the context of short-term memory and item recall, primacy effects are weakened by rapid stimulus presentation (Jahnke, 1968; Tan & Ward, 2000), which is consistent with this assumption. On the other hand, recency effects tend to be smaller when item sequences are short (Tan & Ward, 2000), but in the current series recency effects were detected in the absence of primacy effects with comparably short item sequences. A reason for the functional dissimilarities between the findings in the current series and classic short-term memory effects could be that the task invited item counting as a cognitive strategy. However, while stimulus counting might prevent a disproportionate influence from primacy-items on the estimates, it is unclear why stimulus counting renders the carbon footprint estimates still open to a disproportionate influence from recency-items. Moreover, the assumption that cognitive strategy underpins the absence of a primacy effect in Experiment 1–2 is also difficult to reconcile with the fact that primacy effects where not found when participants self-reported strategies that relied more on memory rather than counting in Experiment 1 (see Table 1). A recency effect, in turn, was found in the context of both self-reported strategies and of similar magnitude.

Therefore, retrospective carbon footprint estimates of temporal item sequences appears to share more functional features with episode-related affect (Alaybek et al., 2022; Fredrickson, 2000; Schreiber & Kahneman, 2000) than with short-term recall. While the role of memory in retrospective affect estimates has been debated (Anderson, 1981; Aldrovandi et al., 2015; Hastie & Park, 1986; Hoffmann & Hosch, 2023; Lichtenstein & Srull, 1987; Montgomery & Unnava, 2009), we found that recency effects in retrospective carbon footprint estimates of item sequence were independent of whether a counting, or a mnemonic strategy was used by the participants. Similar to Aldrovandi et al. (2015), the participants in our experiment were aware of the upcoming estimation task at stimulus presentation and could therefore make continuous, on-line judgments during item presentation. In their study, retrospective affect estimates were adjusted based on retrieval and primarily influenced by the most readily available information from memory. In the experiments reported in the current paper, participants remembered environmentally significant items presented at primacy, as sequences comprising environmentally significant primacy items were assigned a different carbon footprint than sequences comprising environmentally neutral items only. If participants did not remember the primacy item, estimates of sequences comprising environmentally significant primacy items should be similar to that of sequences comprising environmentally neutral items only, but they were not. Therefore, the absence of a primacy effect cannot be simply attributed to a lack of a memory trace of primacy items. The relatively larger effect from environmentally significant items presented at recency, however, suggests that these items were more readily available in memory at the time of the estimate. Future research should try to obtain direct evidence for this assumed underpinning explanation and relate carbon footprint estimates of item sequences to the availability of items in memory.

It should also be noted that past research has questioned the existence of an inherent ending effect. Tully and Meyvis (2016) failed to find clear evidence of an ending effect across several experiments. For example, they found that while extending an experience with a less intense ending resulted in less extreme global evaluations of that experience, adding the less intense segment in the beginning or middle rather than at the end produced the same results. They concluded that the change in global evaluations was underpinned by a change in the stimuli's average—which manifests regardless of *when* during the experience the less intense moment was presented—rather than the experience' final intensity. The authors argued that endings might have an over-weighted effect on global judgments when, for example, endings carry special meaning in terms of closure or resolution, or when memory constraints make it difficult or impossible to recall the earlier part of the experience. In the studies reported here, the ending was not more meaningful than the beginning or the middle; the sequences were relatively short, so the ending/recency effect can hardly be attributed to an inability to recall the beginning; and the presentation of the environmentally significant item shifted the sequence average, but this shift was identical regardless of the serial position of the environmentally significant item. Our results therefore seem to strengthen the case for the existence of inherent ending effects, in contrast to the results reported by Tully and Meyvis (2016), at least in the context of carbon footprint estimates of item sequences.

Another similarity between carbon footprint and affective estimates arises from the effect of peak events. The presentation of many environmentally friendly items at once (a green peak) had a large negating effect of the presence of environmentally harmful items, resulting in a lower carbon footprint estimate of sequences comprising green peaks, red (environmentally harmful) and yellow (environmentally neutral) items, in comparison to estimates of sequences comprising red (environmentally harmful) and yellow (environmentally neutral) items only. In contrast, the presentation of a green peak did not have a similar negating effect of the presence of environmentally neutral items, resulting in a slightly higher but not significantly different estimate of sequences comprising green peaks and yellow items, as compared with estimates of sequences comprising yellow items only. This finding further indicates a functional similarity with the perceived affect of episodes. Items that are contextually outstanding and distinct have a larger effect on perceived carbon footprint, like contextually outstanding events' effect on the perceived affect of episodes (Ariely & Carmon, 2000).

There also appears to be differences between retrospective affective and carbon footprint estimates. One difference is the finding of an effect of sequence length. Duration neglect—that the duration of affective episodes does not influence summative affect estimates—is often seen in the context of affective evaluation of autobiographical long-term memories (Chajut et al., 2014; Rode et al., 2007) and has also been found in immediate estimates of quite short episodes (∼1–2 min; Fredrickson & Kahneman, 1993). The effect of sequence length was, however, very robust in the current series. The reason for this difference between retrospective carbon footprint and affective estimates can be the qualitatively different tasks. Estimating the carbon footprint of item sequences in terms of the items' sum of CO_2 is qualitatively different from estimating summative affective experiences of an episode. For instance, affective moments of various valence can cancel each other out, as is seen by the tendency for affective evaluations to approach the positive and negative moments' average affect (Asutay et al., 2021). In contrast, sequences of items with different degrees of carbon footprint cannot cancel each other out in the same sense as affective responses. Instead, a correct response to a sequence of environmentally significant events should be to assign a higher value to sequences with more items, reflecting an additivity process rather than an averaging process (Holmgren et al., 2021). It should be noted that Schreiber and Kahneman (2000) found a duration effect in the context of affect estimates of very short episodes (8–32 s). In the current series, the shortest sequences had a duration of 2 s and the longest sequences a duration of 6.5 s. It is therefore possible that the apparent difference between carbon footprint and affective estimates is not as large as it might seem. The absence of quantity insensitivity (or duration neglect) in the current series might partly be attributed to the brief sequences and the involvement of immediate memory processes.

6.1.2 | Distinctiveness as a determinant of carbon footprint estimates of item sequences

We think that presenting the green or red items at recency may make them more memorable and hence change the decision-making process. However, it could be that their presence also drives down the memorability of other items within the list—sometimes the presence of an isolate impairs retention of other items in the list (e.g., Schmidt, 2002; Shulz, 1971), but sometimes recall of those items improves (Farrell & Lewandowsky, 2003) and sometimes there is no effect (Kelley & Nairne, 2001). Therefore, one interesting question is what happens to the recallability of the non-distinctive (background) list items. That is, how does the presence of an isolated item (or a distinct green [environmentally friendly] or red [environmentally harmful] item) affect recall of the non-isolated background items (the yellow items) within the list?

From an organizational perspective, some have argued that the isolate promotes the formation of two list-based categories—one containing the isolated item and a second category comprising the background items (Bruce & Gaines, 1976; Fabiani & Donchin, 1995). Because it is easier to recall items from smaller categories, better memory is expected for both the isolate and the background items. Alternatively, if the isolate captures more attentional resources, or is more likely to be rehearsed, then recall of the background items should suffer because they received a smaller proportion of the allocated resources.

Another very intriguing suggestion is that at the end of list recall when people are making their judgements, they may bring to mind the last item first (the distinctive green or red one) which will mean that the other items on the list will be more susceptible to output-interference (e.g., Cunningham et al., 1998; Schmidt, 1985)—that is, people will forget about the earlier items more which then of course affects the judgements. This assumption is consistent with the results of Experiment 3, wherein estimates of sequences with highly distinct environmentally significant items at recency were no different from sequences with highly distinct environmentally significant items at primacy or in the middle. Highly distinct environmentally significant items might more easily come to mind at the time of judgment even when presented earlier in the sequence. This should be modulated by list length, however. It is well-known that participants begin their recall of a relatively long list of items with the one of the last items they encountered (Hogan, 1975; Howard & Kahana, 1999; Laming, 1999). Having said this, it is somewhat more common to start recall of short lists with the first item (Ward et al., 2010). An intriguing avenue for future research would involve the investigation of how carbon footprint estimates are modulated by longer sequences than the ones used in the current series.

The finding that green peaks (multiple presentation of low carbon footprint items at once) had a larger effect in the context of high (red) and intermediate (yellow) carbon footprint items—which differ substantially in valence from the green items—than they had in the context of yellow items only—which differ less in valence from the green items—provides further evidence of the role of distinctiveness. Green items are more categorically distinct from the item background, when all the remainder are yellow, and so any influence of the peak cannot merely be attributed to a distinctiveness effect driven by categorical membership. On average, however, the green items are more prominent from an affect point of view in a sequence within which there's a mixture of red items (from which they differ maximally) and yellow items. The green peaks are hence more distinct from the background context along the environmental-friendliness valence dimension when there's a mixture of red and yellow items in the background, in comparison with when there's only yellow items in the background. On this view, distinctiveness can explain why valence context modulates the peak effects. From an organizational perspective—in turn—when there is a mixture of green, red and yellow items, this promotes the formation of three list-based categories—one comprising the green, one comprising the red and one comprising the yellow items (cf. Fabiani & Donchin, 1995). Items are easier to recall from smaller categories. As a small category among two larger categories, the recallability of the green items should thus have a greater influence on the decision-making process. In conclusion, the results reported here appear to be consistent with an account according to which the distinctiveness of representations in memory bias carbon footprint judgments. It should be noted, though, that distinctiveness theories have been challenged for their logical circularity (see Hunt, 2006).

6.2 | Applied implications

The results reported here are the first demonstration of an ending effect in the evaluation of sequences of environmentally significant events. Memory processes bias evaluations of the environmental footprint of episodes towards the value of the event at the end of the episode. This can have several applied implications for how people evaluate the environmental footprint of things they experience, including the environmental consequences of their consumer behavior. For example, when people go to a shopping mall, the environmental impact of the goods they purchase at the end of the shopping sequence will have a disproportional influence on the perceived carbon footprint of their shopping decisions.

The sequences used in the current series of experiments were relatively short, spanning across just a few seconds. Because of this, the results' generalizability to longer events that rely more on long-term memory rather than short-term memory may be questioned. Yet, human behaviors with environmental consequences can be very brief, such as quick decisions during on-line shopping. Similarly, when watching news reports of some event's environmental significance, the information presentation may be very brief. In view of the results presented here, the news report will leave a stronger impression about the event's environmental consequences if the report ends with significant information.

In view of the functional similarities between retrospective carbon footprint and affective estimates, we anticipate that psychological evaluations of any sequence of events with variable environmental impact will be disproportionately influenced by the final events. The recency effect found here might bias the perceived environmental footprint of any episode, and thus have consequences also on a larger scale. For example, when people evaluate the carbon footprint of their behavior during a week, the evaluation might be disproportionately influenced by the environmental significance of behaviors during the weekend. If they bring a large collection of recyclable trash to the local recycling station by the weekend (which is likely, because most people arguably have time to spare for this during the weekend), for instance, this act might exaggerate people's retrospective estimate of their own pro-environmental behavior, if asked to evaluate their behavior across the week's period.

6.3 | Future directions and conclusions

As argued above, future research should try to obtain direct evidence for the assumption that recency effects in carbon footprint estimates of item sequence manifest because memory of the items at recency is more available or more active than of the items at earlier list positions (cf. Aldrovandi et al., 2015) and explore why the recency effect does not manifest when sequences comprise a mix of items with varying degrees of carbon footprint. Another strand of future research could investigate how basic characteristics of the experimental setup influences the effects. A slower presentation rate could, for example, enhance the influence from first list-items on carbon footprint estimates and thus produce a primacy effect which was not found in the current series with fast presentation rate. Future research could also test the effect of longer sequences as sequence length modulates the recency effect in the context of short-term memory (Ward et al., 2010), and of delaying the carbon footprint estimate. In the context of affective estimates and short-term memory, a delayed response tends to decrease the recency effect (Bjork & Whitten, 1974; Montgomery & Unnava, 2009). Retention intervals can also modulate the peak-end effect in affective experiences (Geng, Chen, Lam, & Zheng, 2013; but see Chajut et al., 2014). This could also provide further exploration of the role of distinctiveness in carbon footprint estimates. The isolation effect can be eliminated if participants are required to undertake an orienting task that requires processing the difference between the current and previous word (Hunt & Lamb, 2001). By analogy, it would be possible to request participants to rate the relative environmental impact of a current target compared to the previous item. In this situation the recency effect might be removed because the effect of distinctiveness should be reduced.

Finally, a target for future research is to test these effects in an experimental paradigm of higher applied validity, such as one in which participants make purchase decisions similar to shopping at a grocery store. A major target of these studies could be to test whether the perceived environmental impact of past consumer behavior has a direct influence of subsequent consumer behavior, manifesting in, for example, negative behavioral spillover (Gholamzadehmir et al., 2019). When past consumer behavior is perceived as relatively environmentally friendly, this could be an obstacle for future pro-environmental behavior. Understanding the role of memory in this spillover process could be utilized in pro-environmental strategies to reduce the carbon footprint of human behavior.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data reported in this paper are available at https://doi.org/10.17605/OSF.IO/J7YRZ.

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