Received: 28 February 2022 | Accepted: 14 November 2022

DOI: 10.1111/bjhp.12637

ARTICLE

the british psychological society
promoting excellence in psychology

# Habit formation in context: Context-specific and context-free measures for tracking fruit consumption habit formation and behaviour

**Svenne Diefenbacher**[1] | **Phillippa Lally**[2] | **Benjamin Gardner**[3]

[1]Department of Social Psychology, Ulm University, Ulm, Germany

[2]Research Department of Behavioural Science and Health, University College London, London, UK

[3]Department of Psychology, University of Surrey, Guildford, UK

**Correspondence**
Svenne Diefenbacher, Department of Social Psychology, Ulm University, 89069 Ulm, Germany.
Email: svenne.diefenbacher@uni-ulm.de

## Abstract

**Objectives:** Interventions promoting habitual fruit consumption have the potential to bring about long-term behaviour change. Assessing the effectiveness of such interventions requires adequate habit and behaviour measures. Habits are based on learned context-behaviour associations, so measures that incorporate context should be more sensitive to expected habit and behaviour changes than context-free measures. This study compared context-specific and context-free measures of fruit consumption habit and behaviour following a 3-week habit formation intervention.

**Design:** Prospective online study ($n$ = 58).

**Methods:** Behaviour frequency was assessed across five timepoints, retrospectively (Time 1 [T1], T5) or via daily diary data (uploaded weekly at T2, T3 and T4). Habit strength was assessed before (T1) and immediately after the intervention (T4), and again 2 weeks later (T5). Analyses of variance were run, with time and context specificity as within-subject factors, and habit and behaviour frequency as dependent measures.

**Results:** An interaction between time and context specificity was found in both analyses (habit: $F(2,114) = 12.848$, $p < .001$, part.$\eta^2 = .184$; behaviour: $F(2,114) = 6.714$, $p = .002$, part.$\eta^2 = .105$). Expected habit formation patterns 5 weeks post-baseline were only detected by the context-specific habit measure. Likewise, increased behaviour frequency was only found when the target context was specified ($p$'s < .001).

**Conclusions:** Assessments of purposeful dietary habit and behaviour change attempts should incorporate context-specific measurement.

**KEYWORDS**
automaticity, behaviour change, fruit consumption, habit, habit formation, health behaviour, measurement, prospective study

**Statement of Contribution**

***What is already known?***

- Forming a fruit consumption habit should sustain fruit intake over time.
- Habits are based on context-behaviour associations.
- Habit measures typically fail to assess context.

***What this study adds***

- This study modelled fruit consumption habit formation and behaviour following an intervention.
- Context-specific habit measures were more sensitive to expected patterns of habit change than were context-free measures.
- Habit formation studies should include context-specific measures.

## BACKGROUND

Regular consumption of fruit can prevent chronic diseases including various forms of cancer and cardiovascular disease (Van Duyn & Pivonka, 2000; Yahia et al., 2017). Nutrition guidelines recommend that people consume five pieces of fruit and vegetables daily (i.e., at least 400 g; World Health Organization, 2003), yet few people meet this goal (Bechthold, 2012). Interventions are needed to increase fruit consumption (Broers et al., 2017). Dietary interventions tend to have positive short-term effects (e.g., Kumanyika et al., 2000), but these often erode over time, as people lose motivation and lapse into old eating patterns (Jeffery et al., 2000). To realize their potential to improve health, dietary interventions must have lasting effects.

Habit formation is thought to be a mechanism for long-term behaviour change (Carden & Wood, 2018; Kwasnicka et al., 2016; Wood & Neal, 2016). 'Habit' has been defined as the process by which exposure to a context activates an impulse to act, based on context-action associations learned through repeated performance, and 'habitual behaviour' describes actions generated by that process (Gardner, 2015). Habit prompts behaviour automatically, potentially in the absence of intention, conscious control or awareness, and with minimal cognitive effort (Bargh, 1994). By virtue of its automaticity, habit has two key effects on behaviour (e.g., Gardner, Lally, & Rebar, 2020). Stronger habits prompt action in associated contexts, such that the action is more likely to be elicited in such contexts (Triandis, 1977). Furthermore, habits can prompt action even where people lack the conscious motivation to act (Gardner, Lally, & Rebar, 2020; Gardner, Rebar, & Lally, 2020; Neal et al., 2011). Predictive studies show that habit strength correlates positively with behaviour frequency, and that habit can override intentions (Gardner et al., 2011; Gardner, Lally, & Rebar, 2020; Gardner, Rebar, & Lally, 2020). These two effects largely underpin current interest in habit from a behaviour change perspective: if new, health-promoting behaviours become habitual, they will likely persist over the long term, by compensating for any motivation loss that might otherwise lead to disengagement (Carden & Wood, 2018; Kwasnicka et al., 2016; Wood & Neal, 2016).

Promoting fruit consumption habits requires an understanding of how habit forms (e.g., Gardner & Lally, 2018; Lally & Gardner, 2013). Habitual behaviours develop through a process of 'context-dependent repetition' (Keller et al., 2021; Lally et al., 2010): performance in a specific context reinforces the context-action association in memory (Rebar et al., 2016; Wood et al., 2014), such that alternative options become less accessible in memory, and the learned response becomes the default (Danner et al., 2008). A seminal study suggested that the relationship between behavioural repetition and habit formation is asymptotic (Lally et al., 2010). Participants formed plans to enact a self-chosen dietary or physical exercise behaviour in response to a cue consistently encountered once daily, and reported habit strength each day. The typical habit development trajectory was characterized by rapid initial gains, which slowed until a plateau was reached. The average time taken to reach the plateau was 66 days, but the observed range (18–254 days) indicated considerable variation in habit formation experiences (Lally et al., 2010). Subsequent research has sought to explore sources of variation in habit formation trajectories (e.g., Fournier et al., 2017) or explore the reproducibility of the asymptotic habit growth curve (e.g., Keller et al., 2021; for a review, see Gardner et al., 2022). Such studies are important for understanding how to promote habit, and thereby maintain behaviour. For example, Lally et al.'s (2010) asymptotic habit growth curve implies that intervention providers should offer the most intensive support in the early stages, but that support can be withdrawn as the habit peak is reached, as the behaviour should become self-sustaining (Gardner, Rebar, & Lally, 2020). Yet, another study observed that no common habit formation trajectory could be found (Schnauber-Stockmann & Naab, 2019). This suggests that motivational support may need to be personally tailored, to best suit each participant's idiosyncratic habit formation growth curve. More research is needed to develop a clearer understanding of the habit formation process.

Modelling the formation of fruit consumption habits requires valid and reliable measures that are sensitive to expected change. Cued automaticity—that is, rapid, non-reflective responding triggered by environmental stimuli—represents the 'active ingredient' of habitual action (Orbell & Verplanken, 2010). Habitual behaviours are consistently performed because they are prompted by impulses directly triggered by associated cues (e.g., Neal et al., 2011; Rees et al., 2018; Verplanken & Roy, 2016). Capturing a habitual response depends on assessing the automaticity of cue responses and the cues that trigger the response. 'Frequency in context' measures assess habit as the multiplicative product of performance frequency and context stability (Labrecque & Wood, 2015; Ouellette & Wood, 1998) but do not capture automaticity. The Self-Report Behavioural Automaticity Index (SRBAI; Gardner et al., 2012)—and its parent scale, the Self-Report Habit Index (SRHI; Verplanken & Orbell, 2003)—tap automaticity, via assessment of participants' agreement with statements regarding the 'symptoms' of automatic responding. Yet, as commonly formulated—e.g., 'Behaviour X is something I do without thinking' (Verplanken & Orbell, 2003)—SRBAI items neglect cues (Sniehotta & Presseau, 2012). The same dietary behaviour (e.g., eating popcorn) may be habitual in one context (e.g., when visiting the cinema; Neal et al., 2011) but deliberative in another (e.g., when bored). Context-free SRBAI items summarize automaticity across contexts (e.g., 'habitual popcorn consumption') so may underestimate the automaticity of habitual responses in one setting (cinema-cued popcorn consumption) and overestimate automaticity of non-habitual responses in other settings (boredom-based consumption). Context-free measures would be expected to lose sensitivity to specific cue responses due to the omission of contextual elements. The SRBAI can be augmented to specify cues ('Behaviour X in Context Y is something…'; Sniehotta & Presseau, 2012), but few studies have done this. In theory, any behaviour can become a habitual response to any cue (Verplanken, 2005), making it potentially difficult to identify relevant cues (Stawarz et al., 2020). However, where cues are known—for example, where participants or researchers identify specific settings in which a behaviour will be repeated as part of a purposeful habit formation attempt (e.g., Keller et al., 2021; Lally et al., 2010;

Phillips et al., 2019)—context-specific habit measures should in theory offer more accurate estimates of changes in the strength of specific habit associations over time.

## The present study

The aim of this study was to compare the sensitivity of context-specific and context-free habit and behaviour measures to anticipated changes in fruit consumption automaticity and behaviour, following a habit formation intervention. It is important to establish which measures are most sensitive to change because insensitive measures may provide misleading findings (see Gardner et al., 2022). An effective dietary habit formation intervention may be erroneously disregarded if, due to measurement error, it appears not to enhance positive dietary habits. Participants were supported to form habits for eating one piece of fruit daily (behaviour) at a self-chosen mealtime (cue) and were tracked over 5 weeks. The intervention sought to promote a 'higher-order' habit, in that we wished to instil habitual impulses to eat fruit with the specified meal while permitting flexibility regarding which specific fruit would be consumed on each occasion (see Phillips et al., 2019). We assumed that, following a planning intervention, participants would form cue-behaviour associations for eating one piece of fruit daily (behaviour) at a self-chosen mealtime (cue; Lally et al., 2010). We expected that, following the intervention, context-specific *habit* measures would more clearly show patterns of expected growth than would context-free measures. We also assessed context-specific and context-free *behaviour* measures because we anticipated that they would track different aspects of behaviour change. That is, context-specific measures should capture engagement in the behaviour in the target context, whereas context-free measures should capture engagement in the behaviour both in the target context and in any other context.

# METHODS

## Design

A longitudinal, repeated measures design was used, whereby all participants completed context-specific and context-free measures of habit strength and behaviour frequency.

## Participants

Participants were recruited in December 2018 via clickworker.de, a German-language recruitment platform open to the general public, and provided written informed consent. The study involved five measurement periods over 5 weeks, comprising three online questionnaires, and two intermediate reports of diary monitoring. Participants who completed all measures received 2€. All procedures were deemed ethically satisfactory according to procedures at the host institution.

Of 126 participants who completed the T1 questionnaire, 58 completed all measures (46.0% of initial sample, $M_{age}$ = 35.3 years, $SD_{age}$ = 11.0, range: 19 to 62 years; 58.6% male, 39.7% female, 0% other, 1.7% missing). Participants were mostly employed or self-employed (63.8%), and 24.1% were university students. Attrition analyses indicated that those who dropped out reported greater context-specific daily fruit consumption at T1 ($M$ = .44, $SD$ = .36) than did completers ($M$ = .31, $SD$ = .35; $p$ = .042), but no other differences were found (all $p$'s ≥ .14).

## Procedure

Table 1 presents an overview of the different study timepoints and measures.

**TABLE 1** Overview of study variables, measures and timepoints

| | T1 | Between T1 & T2 (1 week) | T2 | Between T2 & T3 (1 week) | T3 | Between T3 & T4 (1 week) | T4 | T5 (T4 + 2 w) |
|---|---|---|---|---|---|---|---|---|
| Context-free habit: fruit consumption automaticity | 1–7 | – | – | – | – | – | 1–7 | 1–7 |
| Context-specific habit: fruit consumption automaticity after target meal[a] | 1–7 | – | – | – | – | – | 1–7 | 1–7 |
| Context-free behaviour: fruit consumption frequency | # portions, last 5 days | # portions, daily diary entry | On the 7th day: submission of diary entries | # portions, daily diary entry | On the 7th day: submission of diary entries | # portions, daily diary entry | On the 7th day: submission of diary entries | # portions, last 5 days |
| Context-specific behaviour: fruit consumption frequency after target meal[a] | Yes/no last 5 days | Yes/no daily diary entry | | Yes/no daily diary entry | | Yes/no daily diary entry | | Yes/no last 5 days |
| Habit formation initiation: implementation intentions for eating one piece of fruit after target meal[a] | At the end of the questionnaire | – | – | – | – | – | – | – |

[a]Breakfast, lunch or dinner.

### Time 1 (T1): baseline questionnaire and intervention

At T1, participants completed context-free measures of habit and behaviour. Next, they chose a meal (i.e., breakfast, lunch or dinner) after which they did not currently eat fruit, to be used as the cue to a new habit of eating a piece of fruit daily. Sixteen participants selected breakfast (27.6%) as their target meal, 23 lunch (39.7%) and 19 dinner (32.8%). The chosen meal was used to personalize subsequent context-specific behaviour and habit measures (i.e., 'after breakfast', 'after lunch' or 'after dinner').

Next, participants formed implementation intentions (Gollwitzer, 1999), pairing the target mealtime with the act of consuming one piece of fruit, to facilitate initial context-specific performance and create preliminary context-behaviour associations (Adriaanse & Verhoeven, 2018; Rebar et al., 2016; Rees et al., 2018). An example was provided to aid comprehension (i.e., 'Always after finishing my [breakfast/lunch/dinner], I will eat one portion of fruit'). To reinforce the implementation intentions, participants were shown four photographs depicting typical representations of the respective meal, and four photographs depicting different fruit types, and were asked to select the photographs most correspond with their implementation intention. Participants were given a printable paper diary, to keep a daily record over the following 3 weeks of consumption of a portion of fruit after the chosen meal (i.e., context-specific behaviour) and at any other times during the day (i.e., context-free behaviour).

### T2 (T1 + 1w) and T3 (T1 + 2w): diary monitoring

At T2 and T3, participants received email prompts to log diary data online, thus generating discrete reports of daily context-specific and context-free behaviour data.

### T4 (T1 + 3w): diary monitoring and end-of-intervention questionnaire

At T4, 7 days after the second diary monitoring prompt, a third email prompt was sent to log diary data online (as at T2 and T3) and to complete a questionnaire comprising context-specific and context-free habit measures.

### T5 (T1 + 5w): follow-up questionnaire

At the final timepoint, participants completed context-specific and context-free habit and behaviour measures.

## Measures

### Habit

Context-specific and context-free habit measures were assessed (at T1, T4 and T5) using the SRBAI (Gardner et al., 2012), an automaticity-specific 4-item subset of the SRHI (Verplanken & Orbell, 2003). Context-specific item stems were personally tailored to each participant's chosen mealtime cue: 'eating fruit *after [breakfast/lunch/dinner]* is something…' (e.g., '…I do automatically'), whereas context-free items followed the stem 'eating fruit is something…'. Responses were provided on a 7-point Likert scale (1 [*does not apply at all*]—7 [*completely applies*]). Reliability was good (context-specific: α range across timepoints: .95–.97; context-free: α range .91–.93). Mean scores were computed for analysis purposes.

### Behaviour

Behaviour was measured as actual fruit consumption. At T1 and T5, the context-specific measure asked whether participants had eaten a piece of fruit after their target meal (yes/no) on each of the previous 5 days, and the context-free measure asked about the total number of portions eaten on those 5 days. For both measures, scores were computed to reflect daily fruit consumption.

At T2, T3 and T4, behaviour was reported using diary data. First, participants reported whether, on each of the last 7 days, they had eaten a piece of fruit after their target meal. Second, they entered the number of portions they had eaten *in addition* to fruit consumed after their target meal on each day. The context-specific measure was calculated as the daily consumption of fruits in the target context. The context-free measure was calculated by summing all reported fruit consumption on each day. For analysis purposes, the behaviour reported during the intervention phase in the weekly diaries was averaged across all three diaries (i.e., covering periods T1–T2, T2–T3 and T3–T4) for analysis purposes. We refer to these as 'T2–T4' data from hereon.

## Analyses

To evaluate behaviour and habit development over time as a function of context specificity, 3 (time) × 2 (context specificity) repeated-measure ANOVAs were calculated. For habit, the ANOVA compared T1, T4 and T5 measures with and without context and evaluated the time*context interaction. For behaviour, the ANOVA compared data from T1, T2–T4 (i.e., diary entries averaged across T2, T3 and T4) and T5 measures with and without context and evaluated the time*context interaction. Post hoc analyses for time*context and context*time effects were conducted by applying Bonferroni correction. Statistical power for the performed analyses was determined using the Generic F test option of G*Power 3.1 (i.e., post hoc, given α, non-centrality parameters and dfs). For habit, the power to detect main and interaction effects reported below was at least 93% and for behaviour at least 87%.

# RESULTS

## Tracking habit development using context-specific and context-free measures

Main effects of both time ($F(2,114) = 7.900$, $p < .001$, part.$\eta^2 = .122$) and context specificity ($F(1,57) = 39.751$, $p < .001$, part.$\eta^2 = .411$) on habit were qualified by an interaction between time and context specificity ($F(2,114) = 12.848$, $p < .001$, part.$\eta^2 = .184$; see Figure 1a). For the *context-specific* measure, habit marginally increased from T1 ($M = 2.77$, $SD = 1.77$) to T4 ($M = 3.27$, $SD = 1.73$, $p = .060$) and further increased from T4 to T5 ($M = 3.83$, $SD = 1.72$, $p = .002$), leading to an overall increase between T1 and T5 ($p < .001$). No differences were found for *context-free* habit between T1 ($M = 4.00$, $SD = 1.56$) and T4 ($M = 3.80$, $SD = 1.69$), nor T1 and T5 ($M = 4.16$, $SD = 1.67$; $p$s = 1.000), though an unexpected increase was observed between T4 and T5 ($p = .04$). Thus, the context-*specific* measure demonstrated sensitivity to assumed change but the context-free measure did not. Differences between context-specific and context-free habit values were significant at all three measurement points ($p$s = .002): context-free values were consistently higher than context-specific values, though the magnitude of the difference diminished over time (see Figure 1a).

## Tracking initial behaviour change and behaviour maintenance using context-specific versus context-free measures

Main effects of both time ($F(2,114) = 6.494$, $p = .002$, part.$\eta^2 = .102$) and context ($F(1,57) = 122.946$, $p < .001$, part.$\eta^2 = .683$) were qualified by an interaction between time and context specificity

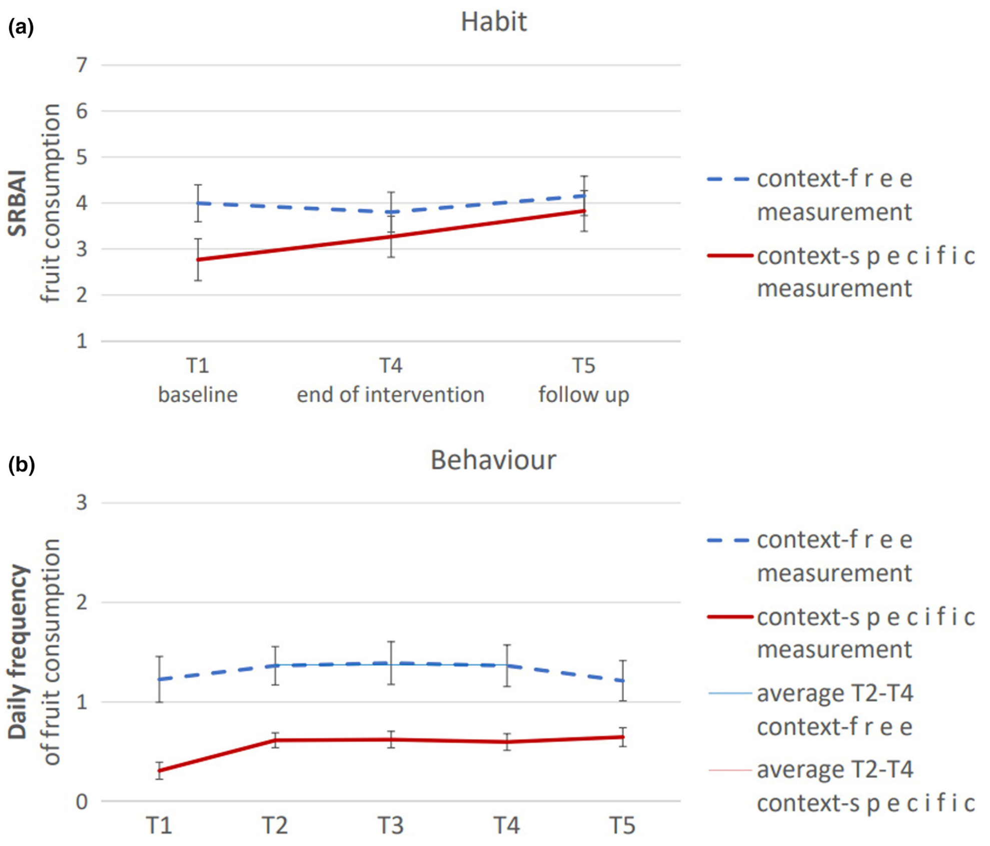


**FIGURE 1** Development of habit (a) and behaviour (b) over time by context specificity (means and 95% confidence intervals)

($F(2,114) = 6.714$, $p = .002$, part.$\eta^2 = .105$; see Figure 1b). Post hoc comparisons showed *context-specific* daily behaviour to increase significantly between T1 and T2-T4 ($M = .61$, $SD = .27$) and remain elevated at T5 ($M = .65$, $SD = .37$) compared with T1 ($M = .31$, $SD = .35$, $ps < .001$). For context-*free* behaviour, there were no differences between T1 ($M = 1.23$, $SD = .90$) and T2-T4 ($M = 1.37$, $SD = .68$, $p = .09$), nor between T1 and T5 ($M = 1.21$, $SD = .78$), nor T2-T4 and T5 ($ps \geq .20$). Thus, the context-*specific* measure of behaviour detected expected early changes, while the context-*free* measure suggested that no changes in behaviour had occurred. Unsurprisingly, given that context-free behaviour values represent context-specific performances and all other occurrences, context-free behaviour scores were consistently higher than context-specific behaviour scores at all measurement points ($ps < .001$; see Figure 1b).

## DISCUSSION

This study demonstrated that, when tracking the development of fruit consumption habits, augmenting habit and behaviour measures to incorporate specific cues enhanced their sensitivity to expected patterns of initial behaviour change, habit formation and behaviour maintenance. We provided participants with an intervention that promoted context-consistent behaviour repetition, which is both theoretically necessary and practically sufficient for the habit to form (Adriaanse & Verhoeven, 2018; Judah et al., 2013; Lally et al., 2010; Rees et al., 2018). Context-specific measures, which included the meal cue chosen by each participant (i.e., after breakfast, lunch or dinner), revealed the sustained gains in automaticity that we expected, but context-free measures did not. Similarly, context-specific measures detected sustained increases in fruit consumption in the target context in response to the intervention, but context-free measures of overall fruit consumption did not show any behaviour change. These findings demonstrate that studies of habit formation and behaviour maintenance may produce different findings according to the sensitivity of habit and behaviour measures to context-consistent performance. Conversely, they highlight the risk of generating misleading findings when tracking habit change using context-free measures, which may prompt erroneous conclusions that the intervention was unsuccessful in promoting habit or behaviour change. Our findings demonstrate the importance of using measures sensitive to the specific situational contexts in which new habits develop (see Sniehotta, 2009).

Absolute habit scores were notably weaker for context-specific than context-free measures. At preintervention, such findings are unsurprising. Eating fruit was not a novel behaviour for our participants, and they chose to form habits in a context in which they did not already eat fruit on a regular basis. Assuming that context-free measures capture responses across multiple contexts, participants should have reported weaker habits in the chosen new context than across all possible contexts (Lally & Gardner, 2013). It is, however, less clear why context-specific habit was weaker than context-free values following the intervention. A habit forms when a specific action is enacted in a specific situation (Gardner et al., 2022), such that a context-specific measure of automaticity—i.e., the extent to which the action is triggered automatically upon exposure to situational cues—should better capture habit (Sniehotta, 2009). One possibility is that, when responding to these items, participants do not estimate the average strength of habit across contexts but rather summate accessible context-specific responses. It may be, for example, that some fruit consumption episodes—for example, habitually eating a piece of fruit with breakfast—are particularly salient or memorable, which enhances their availability in memory when estimating overall automaticity (see Gardner & Tang, 2014). This would suggest that our observed findings represent methodological artifice arising from errors in reflecting on automaticity. An alternative explanation is that gains in habits in one context may transfer to other settings. It may be that successful habit gains in one context (e.g., eating fruit with breakfast) inspire people to attempt to form additional habit associations in other contexts (e.g., eating fruit as a snack in the mid-afternoon). Alternatively, habit associations formed in response to one specific mealtime may, through a process of cue generalization, be extended such that it is cued by any mealtime (Bouton & Todd, 2014).

One surprising finding was that, using both context-specific and context-free measures, habit strength was observed to increase between the end of the intervention period (3 weeks post-baseline) and a follow-up point 2 weeks later (5 weeks post-baseline). Habit is thought to form along an asymptotic growth curve, whereby early repetitions cause the greatest habit gains, which level off as a peak is reached (Fournier et al., 2017; Lally et al., 2010). Alternatively, it may follow a quadratic curve, whereby the habit peak is followed by a slight decline in habit strength (Keller et al., 2021). The delayed strengthening of habit that we observed does not fit either an asymptotic or quadratic pattern. Context-free measures should, in theory, capture habitual performance across multiple contexts. It might therefore be argued that, for context-free measures, growth at later stages might reflect that, inspired by the development of fruit consumption habits in their chosen context (e.g., eating fruit after breakfast), participants adopted new fruit consumption habits in other contexts (eating fruit as an afternoon snack). However, delayed gains in habit strength were observed using both context-free and context-specific measures, suggesting that such increases occurred in the chosen context. It is not immediately clear why such effects should have been observed. One potential explanation is that the mindful self-monitoring of behaviour that was required of participants during the intervention period suppressed the development of automaticity such that, when the intervention period ceased, fruit consumption became a less mindful, more automatic response. Further research is, however, needed to establish the replicability of delayed fruit consumption habit formation and, if replicated, investigate potential explanations for such effects.

Our findings suggest that the formation of fruit consumption habits may be best detected by context-dependent measures. We therefore recommend the use of context-specific measures when assessing the effects of fruit consumption interventions on habit and behaviour maintenance. While our study focused on 'making' fruit consumption habits, our findings also have important implications for tracking the 'breaking' of habits (Adriaanse & Verhoeven, 2018; Bayer et al., 2022). Habit associations can be 'broken' by directly substituting an old for a new habit (Wood & Neal, 2007). This process involves overwriting an old habitual response by consistently performing a new response to the same cue until the new response assumes dominance over the old response in memory (Gardner, Rebar, & Lally, 2020). Context-specific measures are likely to be useful for monitoring the concurrent degradation of old habit associations and the formation of new responses. However, we acknowledge two important caveats to the generalizability of our findings, surrounding the superiority of context-specific fruit consumption habit measures, to habitual behaviours more broadly. Firstly, fruit consumption can feasibly be undertaken in many different contexts, and so, context-specific and context-free measures would be expected to yield different values. For behaviours that occur in few contexts—for example, flossing, which typically occurs once daily as part of a morning or evening routine, in a bathroom (Judah et al., 2013)—context-specific and context-free scores would be expected to be highly similar. For such behaviours, context-specific measures may confer little advantage over context-free measures. Secondly, we were able to model context-specific responses because, as part of our intervention, we offered participants three researcher-selected options regarding settings in which to form new habits (i.e., three mealtimes; Gardner & Lally, 2018). It is difficult to assess context-specific responses where cues are not known. This is not necessarily easily remedied by asking participants to identify cues: due to the automatic nature of habitual responding, people may lack insight into the cues to their habitual responses (Adriaanse & Verhoeven, 2018; Hollands et al., 2016; Sniehotta & Presseau, 2012). Context-specific measures that focus on the 'wrong' cue—e.g., assessing habitual fruit consumption after breakfast, among people who have formed habits for eating fruit at lunchtime—will likely overlook habitual responses to other contexts.

Although we recommend incorporating context into habit measures when studying habit change, informative assessment of behaviour might require both context-specific and context-free measures. Our results indicated that, while fruit consumption in the chosen context increased, the absence of an increase in context-free consumption suggests that participants may have compensated by reducing fruit consumption in other contexts (e.g., Prinsen et al., 2019). Any such compensatory effects would not be detected by a context-specific measure. Researchers should consider employing both generic (i.e., context-free) and context-specific behaviour frequency measures for a more comprehensive account of the impact of context-specific interventions on behaviour.

Limitations must be acknowledged. We relied on self-report measures of fruit consumption, but it is well-documented that self-reports overestimate engagement in healthy behaviours (Lechner et al., 1997). Although participants completed daily fruit consumption diaries, which we assumed would capture consumption more accurately than a single retrospective report of the past 7 days (Miller et al., 2008), any attempts to replicate our study should use more objective fruit consumption measures (e.g., Phillips et al., 2019). However, while self-report may have overstated fruit consumption per se, there is no reason to believe that biases in reporting produced differences in scores on the two habit indices or their apparent sensitivity to habit change.

Another limitation is that the study took place over just 5 weeks. Future studies might investigate the importance of context for habit change across longer periods. One study found that, over a 12-week period, habit formation followed a quadratic growth curve, with early rapid gains slowing to a peak before deteriorating at around 8 weeks, albeit to a level higher than the baseline (Keller et al., 2021). Our measurement of habit formation over a period of just 2 weeks will have overlooked such longer-term patterns of habit change. Additionally, conducting the study online may have biased our sample towards younger, more technologically literate people. However, there is no reason to expect the habit formation process to differ between younger people versus others. Studies demonstrate evidence of formation—and reliable self-reporting—of new habits for young people (e.g., Gardner et al., 2014) and older adults alike (e.g., Matei et al., 2015). Potential age effects should not therefore affect the validity of our central finding, that context-specific measures may be more useful than context-free measures. Lastly, data were partly collected over the Christmas and New Year period, which for many is characterized by atypical behavioural patterns and contexts (e.g., visiting relatives), which may have reduced the impact of the intervention, and habit development more broadly.

## CONCLUSIONS

This study testifies to the importance of specifying the target context when tracking changes in fruit consumption habits and behaviour over time. Context-free habit measures likely lack the sensitivity to document gains in cued automaticity, the 'active ingredient' of habitual action. To capture the behaviour that leads to this habit change, context-specific behaviour measures are needed. We suggest that researchers monitoring changes in habit strength, in relation to fruit consumption and other behaviours, consider accounting for specific cues to habitual responses in their measures. It may, however, also be informative to measure context-free behaviours to assess the wider impact of interventions, such as compensatory effects, whereby increased behavioural engagement in one context is accompanied by declines in others.

### AUTHORS' CONTRIBUTIONS

All authors participated in defining the research questions of the present study and contributed to the interpretation of results. SD was responsible for the preparation of materials, data collection as well as data preparation and performed the analyses reported in this paper. SD and BG drafted the manuscript. PL provided critical feedback and substantially contributed to shaping the manuscript. All authors read and approved the final manuscript.

### ACKNOWLEDGEMENTS

The authors thank Michael Berger, Angelika Fünfgeld, Nadja Mack, Thomas Lautenschlager and Laura Wevelsiep for their help and dedication during data collection and processing.

Open Access funding enabled and organized by Projekt DEAL.

### FUNDING INFORMATION

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### ETHICAL APPROVAL

The reported study was deemed ethically satisfactory according to procedures at the host institution and all participants provided written informed consent (as stated in the 'Methods' section). The study was conducted in full accordance with the Ethical Guidelines of the German Association of Psychologists (DGPs). Please note that at the time the study was conducted (December 2018–January 2019), it was neither mandatory nor customary at the host site to seek ethics approval for simple, non-invasive field studies such as this.

### INFORMED CONSENT

Not applicable.

### ORCID

*Svenne Diefenbacher* https://orcid.org/0000-0001-7560-2565
*Phillippa Lally* https://orcid.org/0000-0002-4847-4163
*Benjamin Gardner* https://orcid.org/0000-0003-1223-5934

## REFERENCES

Adriaanse, M. A., & Verhoeven, A. (2018). Breaking habits using implementation intentions. In B. Verplanken (Ed.), *The psychology of habit* (pp. 207–229). Springer.

Bargh, J. A. (1994). The four horsemen of automaticity: Awareness, intention, efficiency, and control in social cognition. In R. S. Wyer, Jr. & T. K. Srull (Eds.), *Handbook of social cognition: Basic processes; applications* (pp. 1–40). Lawrence Erlbaum Associates, Inc.

Bayer, J. B., Anderson, I. A., & Tokunaga, R. S. (2022). Building and breaking social media habits. *Current Opinion in Psychology*, *45*, 279–288. https://doi.org/10.1016/j.copsyc.2022.101303

Bechthold, A. (2012). Gemüse- und Obstkonsum. In H. Boeing, A. Bechthold, A. Bub, S. Ellinger, D. Haller, A. Kroke, et al. (Eds.), *Stellungnahme. Gemüse und Obst in der Prävention ausgewählter chronischer Krankheiten. Stellungnahme der DGE eV* (pp. 5–9). Deutsche Gesellschaft für Ernährung https://www.dge.de/fileadmin/public/doc/ws/stellungnahme/DGE-Stellungnahme-Gemuese-Obst-2012.pdf

Bouton, M. E., & Todd, T. P. (2014). A fundamental role for context in instrumental learning and extinction. *Behavioural Processes*, *104*, 13–19. https://doi.org/10.1016/j.beproc.2014.02.012

Broers, V. J., De Breucker, C., Van den Broucke, S., & Luminet, O. (2017). A systematic review and meta-analysis of the effectiveness of nudging to increase fruit and vegetable choice. *European Journal of Public Health*, *27*(5), 912–920. https://doi.org/10.1093/eurpub/ckx085

Carden, L., & Wood, W. (2018). Habit formation and change. *Current Opinion in Behavioral Sciences*, *20*, 117–122. https://doi.org/10.1016/j.cobeha.2017.12.009

Danner, U. N., Aarts, H., & De Vries, N. K. (2008). Habit vs. intention in the prediction of future behaviour: The role of frequency, context stability and mental accessibility of past behaviour. *British Journal of Social Psychology*, *47*(2), 245–265. https://doi.org/10.1348/014466607X230876

Fournier, M., d'Arripe-Longueville, F., Rovere, C., Easthope, C. S., Schwabe, L., El Methni, J., & Radel, R. (2017). Effects of circadian cortisol on the development of a health habit. *Health Psychology*, *36*, 1059–1064. https://doi.org/10.1037/hea0000510

Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behaviour. *Health Psychology Review*, *9*, 277–295. https://doi.org/10.1080/17437199.2013.876238

Gardner, B., Abraham, C., Lally, P., & de Bruijn, G. J. (2012). Towards parsimony in habit measurement: Testing the convergent and predictive validity of an automaticity subscale of the self-report habit index. *International Journal of Behavioral Nutrition and Physical Activity*, *9*, 102. https://doi.org/10.1186/1479-5868-9-102

Gardner, B., de Bruijn, G.-J., & Lally, P. (2011). A systematic review and meta-analysis of applications of the self-report habit index to nutrition and physical activity behaviours. *Annals of Behavioral Medicine*, *42*, 174–187. https://doi.org/10.1007/s12160-011-9282-0

Gardner, B., & Lally, P. (2018). Modelling habit formation and its determinants. In B. Verplanken (Ed.), *The psychology of habit* (pp. 207–229). Springer.

Gardner, B., Lally, P., & Rebar, A. L. (2020). Does habit weaken the relationship between intention and behaviour? Revisiting the habit-intention interaction hypothesis. *Social and Personality Psychology Compass*, *14*, e12553. https://doi.org/10.1111/spc3.12553

Gardner, B., Rebar, A. L., & Lally, P. (2020). Habit interventions. In M. S. Hagger, L. D. Cameron, K. Hamilton, N. Hankonen, & T. Lintunen (Eds.), *The handbook of behavior change* (pp. 599–616). Cambridge University Press.

Gardner, B., Rebar, A. L., & Lally, P. (2022). How does habit form? Guidelines for tracking real-world habit formation. *Cogent Psychology*, *9*(1), 2041277. https://doi.org/10.1080/23311908.2022.2041277

Gardner, B., Sheals, K., Wardle, J., & McGowan, L. (2014). Putting habit into practice, and practice into habit: A process evaluation and exploration of the acceptability of a habit-based dietary behaviour change intervention. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 1–13. https://doi.org/10.1186/s12966-014-0135-7

Gardner, B., & Tang, V. (2014). Reflecting on non-reflective action: An exploratory think-aloud study of self-report habit measures. *British Journal of Health Psychology*, *19*, 258–273. https://doi.org/10.1111/bjhp.12060

Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist*, *54*, 493–503. https://doi.org/10.1037/0003-066X.54.7.493

Hollands, G. J., Marteau, T. M., & Fletcher, P. C. (2016). Non-conscious processes in changing health-related behaviour: A conceptual analysis and framework. *Health Psychology Review*, *10*, 381–394. https://doi.org/10.1080/17437199.2015.1138093

Jeffery, R. W., Drewnowski, A., Epstein, L. H., Stunkard, A. J., Wilson, G. T., & Wing, R. R. (2000). Long-term maintenance of weight loss: Current status. *Health Psychology*, *19*(Suppl. 1), 5–16. https://doi.org/10.1037/0278-6133.19.suppl1.5

Judah, G., Gardner, B., & Aunger, R. (2013). Forming a flossing habit: An exploratory study of the psychological determinants of habit formation. *British Journal of Health Psychology*, *18*, 338–353. https://doi.org/10.1111/j.2044-8287.2012.02086.x

Keller, J., Kwasnicka, D., Klaiber, P., Sichert, L., Lally, P., & Fleig, L. (2021). Habit formation following routine-based versus time-based cue planning: A randomized controlled trial. *British Journal of Health Psychology*, *26*(3), 807–824. https://doi.org/10.1111/bjhp.12504

Kumanyika, S. K., Bowen, D., Rolls, B. J., Van Horn, L., Perri, M. G., Czajkowski, S. M., & Schron, E. (2000). Maintenance of dietary behavior change. *Health Psychology*, *19*(1, Suppl), 42–56. https://doi.org/10.1037/0278-6133.19.Suppl1.42

Kwasnicka, D., Dombrowski, S. U., White, M., & Sniehotta, F. (2016). Theoretical explanations for maintenance of behaviour change: A systematic review of behaviour theories. *Health Psychology Review*, *10*, 277–296. https://doi.org/10.1080/17437199.2016.1151372

Labrecque, J. S., & Wood, W. (2015). What measures of habit strength to use? comment on gardner (2015). *Health Psychology Review*, *9*(3), 303–310. https://doi.org/10.1080/17437199.2014.992030

Lally, P., & Gardner, B. (2013). Promoting habit formation. *Health Psychology Review*, *7*(Suppl 1), S137–S158. https://doi.org/10.1080/17437199.2011.603640

Lally, P., Van Jaarsveld, C. H., Potts, H. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, *40*, 998–1009. https://doi.org/10.1002/ejsp.674

Lechner, L., Brug, J., & De Vries, H. (1997). Misconceptions of fruit and vegetable consumption: Differences between objective and subjective estimation of intake. *Journal of Nutrition Education*, *29*, 313–320. https://doi.org/10.1016/S0022-3182(97)70245-0

Matei, R., Thuné-Boyle, I., Hamer, M., Iliffe, S., Fox, K. R., Jefferis, B. J., & Gardner, B. (2015). Acceptability of a theory-based sedentary behaviour reduction intervention for older adults ('on your feet to earn your seat'). *BMC Public Health*, *15*(1), 1–16. https://doi.org/10.1186/s12889-015-1921-0

Miller, T. M., Abdel-Maksoud, M. F., Crane, L. A., Marcus, A. C., & Beyers, T. E. (2008). Effects of social approval bias on self-reported fruit and vegetable consumption: A randomized controlled trial. *Nutrition Journal*, *7*, 18. https://doi.org/10.1186/1475-2891-7-18

Neal, D. T., Wood, W., Wu, M., & Kurlander, D. (2011). The pull of the past: When do habits persist despite conflict with motives? *Personality and Social Psychology Bulletin*, *37*, 1428–1437. https://doi.org/10.1177/0146167211419863

Orbell, S., & Verplanken, B. (2010). The automatic component of habit in health behavior: Habit as cue-contingent automaticity. *Health Psychology*, *29*(4), 374–383. https://doi.org/10.1037/a0019596

Ouellette, J. A., & Wood, W. (1998). Habit and intention in everyday life: The multiple processes by which past behavior predicts future behavior. *Psychological Bulletin*, *124*, 54–74. https://doi.org/10.1037/0033-2909.124.1.54

Phillips, L. A., Johnson, M., & More, K. R. (2019). Experimental test of a planning intervention for forming a 'higher order' health-habit. *Psychology & Health*, *34*, 1328–1346. https://doi.org/10.1080/08870446.2019.1604956

Prinsen, S., Evers, C., & de Ridder, D. T. D. (2019). Justified indulgence: Self-licensing effects on caloric consumption. *Psychology & Health*, *34*, 24–43. https://doi.org/10.1080/08870446.2018.1508683

Rebar, A. L., Dimmock, J. A., Jackson, B., Rhodes, R. E., Kates, A., Starling, J., & Vandelanotte, C. (2016). A systematic review of the effects of non-conscious regulatory processes in physical activity. *Health Psychology Review*, *10*, 395–407. https://doi.org/10.1080/17437199.2016.1183505

Rees, J. H., Bamberg, S., Jäger, A., Victor, L., Bergmeyer, M., & Friese, M. (2018). Breaking the habit: On the highly habitualized nature of meat consumption and implementation intentions as one effective way of reducing it. *Basic and Applied Social Psychology*, *40*, 136–147. https://doi.org/10.1080/01973533.2018.1449111

Schnauber-Stockmann, A., & Naab, T. K. (2019). The process of forming a mobile media habit: Results of a longitudinal study in a real-world setting. *Media Psychology*, *22*(5), 714–742. https://doi.org/10.1080/19312458.2020.1784402

Sniehotta, F. F. (2009). Towards a theory of intentional behaviour change: Plans, planning, and self-regulation. *British Journal of Health Psychology*, *14*, 261–273. https://doi.org/10.1348/135910708X389042

Sniehotta, F. F., & Presseau, J. (2012). The habitual use of the self-report habit index. *Annals of Behavioral Medicine*, *43*, 139–140. https://doi.org/10.1007/s12160-011-9305-x

Stawarz, K., Gardner, B., Cox, A., & Blandford, A. (2020). What influences the selection of contextual cues when starting a new routine behaviour? An exploratory study. *BMC Psychology*, *8*, 29. https://doi.org/10.1186/s40359-020-0394-9

Triandis, H. C. (1977). *Interpersonal behavior*. Brooks/Cole Pub. Co.

Van Duyn, M. A. S., & Pivonka, E. (2000). Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: Selected literature. *Journal of the American Dietetic Association*, *100*(12), 1511–1521. https://doi.org/10.1016/S0002-8223(00)00420-X

Verplanken, B. (2005). Habits and implementation intentions. In J. Kerr, R. Weitkunat, & M. Moretti (Eds.), *The ABC of Behavioural change* (pp. 99–109). Elsevier.

Verplanken, B., & Orbell, S. (2003). Reflections on past behavior: A self-report index of habit strength. *Journal of Applied Social Psychology*, *33*, 1313–1330. https://doi.org/10.1111/j.1559-1816.2003.tb01951.x

Verplanken, B., & Roy, D. (2016). Empowering interventions to promote sustainable lifestyles: Testing the habit discontinuity hypothesis in a field experiment. *Journal of Environmental Psychology*, *45*, 127–134. https://doi.org/10.1016/j.jenvp.2015.11.008

Wood, W., Labrecque, J. S., Lin, P.-Y., & Rünger, D. (2014). Habits in dual process models. In J. Sherman, B. Gawronski, & Y. Trope (Eds.), *Dual process theories of the social mind* (pp. 371–385). Guilford Press.

Wood, W., & Neal, D. T. (2007). A new look at habits and the habit-goal interface. *Psychological Review*, *114*, 843–863. https://doi.org/10.1037/0033-295X.114.4.843

Wood, W., & Neal, D. T. (2016). Healthy through habit: Interventions for initiating & maintaining health behavior change. *Behavioral Science & Policy*, *2*, 71–83. https://doi.org/10.1353/bsp.2016.0008

World Health Organization (2003). Diet, nutrition and the prevention of chronic diseases. In *World Health Organization technical report series, 916*. World Health Organization. Available online: https://apps.who.int/iris/bitstream/handle/10665/42665/WHO_TRS_916.pdf

Yahia, E. M., Maldonado Celis, M. E., & Svendsen, M. (2017). The contribution of fruit and vegetable consumption to human health. In E. M. Yahia (Ed.), *Fruit and vegetable phytochemicals: Chemistry and human health* (2nd ed., pp. 3–52). Wiley Blackwell.

**How to cite this article:** Diefenbacher, S., Lally, P., & Gardner, B. (2022). Habit formation in context: Context-specific and context-free measures for tracking fruit consumption habit formation and behaviour. *British Journal of Health Psychology*, *00*, 1–14. https://doi.org/10.1111/bjhp.12637