Appetite 160 (2021) 105116

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Under pressure: Nudging increases healthy food choice in a virtual reality supermarket, irrespective of system 1 reasoning

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ARTICLE INFO

Keywords:
Nudging
Healthy eating
Food choices
Virtual supermarket
Dual processing

ABSTRACT

Previous research has shown that nudging can effectively support people's healthy food choices. Yet, to date knowledge about the psychological premises of nudging is limited, highlighting the need for closer scrutiny to determine how and when nudging is most effective. In the current study, we assessed whether the presumed effect of nudging on healthy food choice is enhanced under time pressure, a condition probing alleged system 1 reasoning. Food choice was studied in a realistic virtual reality supermarket where healthier alternatives were nudged by making them more salient. We additionally explored possible differences in decision-making experiences related to nudging or time pressure. The study took place at a science festival where visitors could decide to participate in a study. Participants (n = 99) had to purchase four products, each from a different product category that was provided on a shopping list. In the nudging condition, one healthier option within each product category was nudged by making it more salient. While a main effect of nudging was found, showing in increased healthy food choices, this effect was not further qualified by time pressure, suggesting that the effectiveness of nudging is not enhanced under system 1 conditions. Relatedly, people who were and who were not aware of the nudges showed similar effects of nudging on healthy food choice. Furthermore, no differences in decision-making experiences showed, suggesting that people have similar experiences regarding impulsive and reflective decision-making irrespective of whether they are being nudged or put under time pressure. All in all, our findings are in line with recent viewpoints on the premises of nudges, suggesting that alleged system 1 conditions are not a prerequisite for nudging to be effective.

1. Introduction

Imagine someone rushing through the supermarket to get ingredients for that day's dinner before the supermarket closes. Standing in front of the shelves, confronted with all sorts of options, and the clock is ticking: How to decide which pasta or dessert to take? Very likely, this person will not elaborate extensively on this question, but will just pick the products that catch their attention. Such automatic decisions are exactly the target of nudges, i.e. small modifications in the environment in which individuals make choices (Hollands et al., 2013) that gently steer people's behavior towards choosing a more favorable option (Thaler & Sunstein, 2008); the option that is thought to be in the individual's or society's best interest (Bovens, 2009), for example, the healthier option. Several recent meta-analyses show that nudging can effectively increase healthy food choices (Arno & Thomas, 2016; Broers, De Breucker, Van den Broucke, & Luminet, 2017; Bucher et al., 2016; Cadario & Chandon, 2020). This is especially relevant considering the fact that overall, even though people intend to eat healthily (De Ridder, Adriaanse, Evers, & Verhoeven, 2014), they often do not succeed in this in daily life (De Ridder, Kroese, Evers, Adriaanse, & Gillebaart, 2017). The so called 'obesogenic environment' is considered an important factor for unhealthy eating behavior (De Ridder et al., 2017), underlining the relevance of nudging to support individuals in making healthier food choices.

Yet, to date knowledge about the psychological premises of nudging is limited (Marchiori, Adriaanse, & De Ridder, 2017), highlighting the need for closer scrutiny to determine how and when nudging is most effective (De Ridder et al., 2020a). Nudging has proven a cost-effective public policy tool, and is implemented in numerous countries (Benartzi et al., 2017) on a variety of policy areas, such as health and wellbeing (e.

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https://doi.org/10.1016/j.appet.2021.105116
Received 15 May 2020; Received in revised form 27 November 2020; Accepted 9 January 2021
Available online 12 January 2021

g., The Behavioural Insights Team, 2015). Yet, despite its popularity as policy tool and the converging evidence on its effectiveness, only 24% of the studies investigating nudges focused on their theoretical underpinnings (Szaszi, Palinkas, Palfi, Szollosi, & Aczel, 2018). Considering the promising results nudging could have when applied effectively to support people's healthy food choices, it is thus not only important to examine whether nudging can increase healthy food choice, but specifically to examine which contextual factors influence the effectiveness of nudging healthy food choices. In the current study we will examine the possible influence of time pressure on the effectiveness of a nudge that increases the salience of healthier options in a supermarket environment. Salience nudges (Blumenthal-Barby & Burroughs, 2012) make certain options stand out and are similar to traditional marketing strategies utilized in supermarket settings (Hoenink et al., 2020), which would make them easily implementable in physical supermarkets, while also representing an ecologically valid supermarket setting.

1.1. Nudging healthier options: the role of system 1 and system 2 reasoning

Originally, the concept of nudging stems from dual process theories of human behavior, stating that people make behavioral decisions applying different types of reasoning, namely fast and automatic reasoning (also referred to as system 1) or reflective and slow (also referred to as system 2) reasoning (e.g., Evans, 2008; Kahneman, 2003; Melnikoff & Bargh, 2018). Traditional educational interventions often overlook the automatic aspects of human behavior, possibly explaining their limited effectiveness (Marchiori et al., 2017). Nudges, on the contrary, are theorized to work by redirecting system 1 reasoning, taking into account the fact that humans do not always arrive at their decisions in a deliberate manner (e.g., Gigerenzer, 2015). Nudges aim to harness (Gigerenzer & Gaissmaier, 2011) or to take advantage of decision-making heuristics (Kahneman, 2003): the automatic processes that tend to operate efficiently when individuals are facing limited time, knowledge, or cognitive resources (Gigerenzer & Gaissmaier, 2011). It is as such generally assumed that nudges operate in a particular effective fashion under system 1 conditions, where human reasoning is characterized as fast and automatic (Marchiori et al., 2017).

Yet, the current literature reports contradictory results regarding this assumption. Some studies seem to support the notion that nudging healthy food choices is indeed most effective when individuals rely more on system 1 reasoning, for example under conditions of ego-depletion (Salmon et al., 2015; Salmon, Fennis, De Ridder, Adriaanse, & De Vet, 2014), low self-control (Koenigstorfer, Groeppel-Klein, & Kamm, 2014), or hunger (Forwood, Ahern, Hollands, Ng, & Marteau, 2015). Furthermore, it has been suggested that impulsive food choices might be especially prone to influence by nudging, as demonstrated by ample studies that placed healthy food products at the checkout or end-of-aisles (e.g., Adjoian, Dannefer, Willingham, Brathwaite, & Franklin, 2017; Kroese, Marchiori, & De Ridder, 2016; Van Gestel, Kroese, & De Ridder, 2018; Van Kleef, Otten, & Van Trijp, 2012; Winkler, Berger, Filipiak-Pittroff, Hartmann, & Streber, 2018). On the other hand, research has reported that conditions that induce system 1 reasoning do not -always- increase the effectiveness of nudging healthy food choice. One study for example found no difference in nudge effectiveness between individuals with low vs. high depletion of self-regulatory resources (Missbach & König, 2016), and another study reported no difference between individuals under low vs. high self-control (Hunter, Hollands, Couturier, & Marteau, 2018). In a similar vein, explicitly explaining the presence of a nudge does not necessarily undermine the effect of nudging on healthy food choices (e.g., Bruns, Kantorowicz-Reznichenko, Klement, Jonsson, & Rahali, 2018; Kroese et al., 2016; Van Gestel et al., 2018). Though this does not automatically mean that participants employed more deliberate system 2 reasoning, it does suggest that having the option to employ system 2 reasoning does not seem to render nudges ineffective. In fact, recent research found that a default nudge was effective in increasing the number of green amenities (e.g., an energy-efficient oven and stove) chosen both under system 1 and system 2 conditions, supporting the notion that system 2 reasoning does not undermine nudge effectiveness (Van Gestel, Adriaanse & De Riddder, 2020).

All in all, the assumption that nudging would be more effective in supporting healthy food choices when individuals are under conditions that induce system 1 reasoning is not unequivocally supported by empirical evidence. One manner in which the influence of system 1 reasoning on the effectiveness of nudging can be examined is by exerting time pressure. Exerting time pressure decreases the duration of information processing and deliberation and hence directly appeals to the concept of fast system 1 reasoning (e.g., Bago & De Neys, 2017). Constraining time can be considered an ecologically valid way of inducing system 1 reasoning in a food choice environment as time constraints in such environments regularly occur in people's daily life. To illustrate, time constraint is reported to be an important barrier to healthy eating and influences people's grocery shopping behavior and diet quality negatively (Jabs & Devine, 2006; Pinho et al., 2018; Rogus, 2018; Welch, McNaughton, Hunter, Hume, & Crawford, 2009). In agreement with these findings, studies investigating time pressure during decision-making seem to suggest that time pressure reduces reflective food choice (Fenko, 2019; Friese, Wänke, & Plessner, 2006). In the current study, we aim to examine whether nudging healthier food choices in a supermarket environment might be more effective under system 1 conditions by using time pressure as a means to induce fast system 1 reasoning (in line with for example Bago & De Neys, 2017).

1.2. Current study

The present study aims to assess whether the presumed effect of nudging on healthy food choice is enhanced under time pressure, a condition probing alleged system 1 reasoning. We studied food choice in a realistic virtual reality (VR) supermarket and nudged participants by putting a frame around healthier alternatives to make them more salient. With respect to the VR supermarket: research has shown that purchases in VR supermarkets resemble the purchases made in physical supermarkets (Waterlander, Jiang, Steenhuis, & Mhurchu, 2015). Similarly, individuals' eye-movements and information-seeking behaviors in VR supermarkets also resemble those occurring in physical supermarkets (Van Herpen, Van den Broek, Van Trijp, & Yu, 2016; Siegrist et al., 2019). We hypothesized that nudging would increase healthy food choices, especially for individuals under time pressure. Furthermore, we explore whether there might be differences in people's decision-making experiences related to nudging or time pressure, by measuring the presence of impulsive and reflective decision-making experiences.

2. Method

2.1. Study design

This study examined healthy food choices in an immersive a virtual reality (VR) supermarket environment. The VR supermarket employed here, was based on the VirtuMart (Van der Laan Papies, Ly & Smeets, 2020), and was adapted for the current study. The VR supermarket was designed in Blender/Unity3D and was experienced by participants employing an HTC Vive head-mounted display and two hand-held controllers. Participants were either put under high or low time pressure, and either were or were not exposed to nudges for healthy food items. The number of nudged healthy products chosen was the main dependent variable, while we also examined whether nudging might generate an increase in the total number of healthier products chosen, either nudged or unnudged, as a side effect. Additionally, participants' decision-making experiences were measured post-test. Participants were randomly assigned to one of the four conditions.

2.2. Power analysis

In order to estimate the required sample size for this study, an a priori power analysis was performed in G*Power 3.1 for an ANOVA with 4 groups ($\alpha = 0.05$, power = 80%). A moderate effect size of $d = 0.3$ was estimated, based on a meta-analysis (Broers et al., 2017) examining the effect of nudging on healthy food choice. This power analysis revealed that a sample of 90 participants should be sufficient (23 participants per group, rounded up from 22.5).

2.3. Participants

In total, one hundred and fifteen participants participated in this study. Nine participants had to be excluded because they did not correctly follow the instructions. Additionally, seven participants were excluded because they did not finish the shopping task due to difficulties with handling the VR consoles or because they did not fill out the (full) post-test questionnaire. This resulted in a final sample of ninety-nine participants (59 female, $M_{age} = 30.70$ years old, $SD_{age} = 10.90$ years), the majority (79.8%) of whom had attained high levels of education, while 19.2% attained middle levels of education, and 1% attained low levels of education. Attained education equivalent to levels 1–2 of the European Qualifications Framework (European Commission.) were classified as low, levels 3–5 were classified as middle, and levels 6–8 were classified as high levels of education. Excluded participants (who filled out the questionnaire) did not differ significantly from the included participants with regard to the demographic and relevant control measures.

2.4. Procedure

The study took place at an Utrecht University science festival lasting one evening where there were several stands that visitors could approach if they would like to participate in a study. The study was approved by the Ethics Review Board of the Faculty of Social and Behavioral Sciences at Utrecht University and participants were not incentivized for their participation. Participants (at least 18 years old) could participate in a study on decision-making during grocery shopping by approaching the stand of the study and signing an informed consent. Next, they were led into one of two experimental rooms, where participants received a HTC- Vive head-mounted display, through which they could experience the virtual supermarket, and two hand-held controllers, that controlled the virtual hands to pick up products. When participants were fully equipped, the experimenter instructed the participants as follows: "*You are now standing in the virtual supermarket. We would like to ask you to buy four products that you can read from the grocery shopping list displayed on a poster on the wall in front of you. As you can see, these products are a dessert, a bottle of soda, pasta and cheese.*[1] *Within each of these product categories, you can choose one specific item. You can pick up items using the button below your index fingers, and move through the supermarket by walking or by pointing to the spot you want to go to and then pressing the button below your thumbs ("teleporting"). There are two shopping baskets in the supermarket in which you can drop the products that you have chosen. When all four products are in the shopping baskets, you are done with the shopping and can continue with the questionnaire on the computer."*

Participants in the high time pressure condition were also instructed to do their shopping as fast as possible (as if they were in a hurry) and within 3 min, while participants in the low time pressure condition were told that it did not matter how long they would take for the task. We asked people to buy four products: a dessert, soda, pasta and cheese, because these are common products that people might regularly purchase, and because we aimed to measure the effect of nudging healthier options across a variety of food choices. After shopping in the virtual supermarket, people were asked to fill out the questionnaire via Qualtrics on the computer, thanked and debriefed.

2.5. Virtual reality supermarket

Considering that the study took place in the Netherlands, the layout and products of this supermarket were modelled after the products on sale in the biggest Dutch supermarket that most Dutch people are familiar with. The images of the products used in the supermarket were taken from the website of this supermarket (www.ah.nl). Besides the front view of the product packaging, no extra information or description with respect to the products and their characteristics or healthiness was added, in line with the display of products in physical supermarkets. In order to model a common supermarket experience, participants were exposed to various other products besides the products that were on their shopping list. A total of sixteen filler product categories were present (e.g., bread, snacks), next to the four product categories that were on participants' shopping list, meaning that 20 product categories in total were present in the supermarket. The product selection contained well-known brands and store-brand products.

Each product category consisted of twelve product options: six options that were previously pilot tested (n = 56 participants, Van der Laan, Papies, Ly, & Smeets, 2020) and shown to be perceived as relatively healthy ($M = 6.0$, $SD = 0.7$ on a scale ranging from 1 = not healthy at all to 9 = very healthy), which were matched with six options that were previously pilot tested and shown to be perceived as relatively unhealthy ($M = 2.9$, $SD = 0.7$ on a scale ranging from 1 = not healthy at all to 9 = very healthy). To illustrate, one of the healthier dessert options was a low-fat strawberry yoghurt, of which the matched less healthy option was a strawberry pudding. The healthier options of the four product categories from which participants were asked to buy products had a mean energy content of 159.4 kcal/100 g ($SD = 141.2$), while the matched less healthy options had a mean energy content of 222.7 kcal/100 g ($SD = 145.1$).

With respect to the product positioning for the four product categories on participants' shopping list: the six healthy (unhealthy) options were positioned on the left (right) side of the shelves for two product categories (i.e., pasta and soft drinks), while the opposite setup was used for the other two product categories (i.e., cheese and desserts). In the nudge condition, per product category, one out of six of the healthier options was made more salient through surrounding the product with an orange frame, see Fig. 1 for an example.[2] Thus, in the nudge condition, four healthier products in total were highlighted through a frame on the shelves, while these frames were absent in the control condition. All product options and salience frames (in the nudge condition) were in the same place throughout the study. Lastly, participants were not obliged to view all product options before choosing, as we aimed for the decision-process to reflect participants' natural decision-process when choosing a product in the supermarket.

2.6. Measures

Product choice. To investigate whether the nudges were effective in stimulating a healthier food choice, we calculated how many of the

[1] The first participants were also asked to buy toilet paper in order to practice with the VR supermarket. Due to the long waiting line for our experiment, we decided to skip this non-food exercise item after 27 participants. Participants with and without the practice item did not differ significantly from each other in terms of the experience of the VR supermarket or the time they needed to finish the task.

[2] The position of the nudged *healthier* option with salience frame varied as follows: upper left healthier option for the nudged cheese, upper right healthier option for the nudged dessert, upper right healthier option for the nudged pasta, and lower right healthier option for the nudged soft drink, respectively.

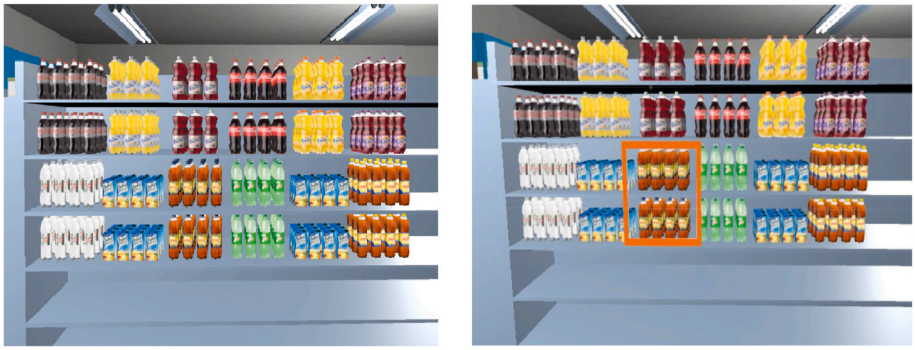

Fig. 1. Example of shelves without (left) and shelves with (right) a salience nudge used in the current study.

products chosen by the participants were *nudged products*. This number could range from zero to four. Additionally, we also calculated how many of the products chosen by participants were *healthier products,* either nudged or unnudged. This number could also range from zero to four.

Objective time spent. To measure to what extent people made faster choices in the time pressure conditions, the VR supermarket registered how long each shopping trip lasted. Because people already wore the headset with the supermarket displayed during the instructions, the time registration started before participants actually started the task. Hence, in order to reliably calculate and compare how long participants' decisions took, we looked at the time from the first purchase onwards until the last purchase.

Decision-making experience. Post-test, we measured reflective decision-making experience with the question "*Did you think carefully when choosing the products?*". Secondly, we measured impulsive decision-making experience with the question "*Did you choose the products in an impulse?*".[3] These questions were to be answered with yes or no. These questions were based on items from a 15-item questionnaire about decision-making experiences that was previously pilot tested and validated in a large sample (n = 1140). Due to limitations for the duration of the current study, one question was distilled per decision-making experience, based on the items that showed largest corrected item-total correlations per decision-making experience scale in the pilot study.

Subjective time pressure. To measure to what extent people felt pressured in the time pressure conditions, we used two questions. The first item asked about time pressure ("*How much time pressure did you experience while shopping in the virtual supermarket?*"), ranging from *no time pressure at all* (1) to *a lot of time pressure* (7) and the second item asked about stress ("*How much stress did you experience while shopping in the virtual supermarket?*"), ranging from *no stress at all* (1) to *a lot of stress* (7).

Awareness of the nudge. To assess whether participants in the nudge condition remembered noticing the nudges in the VR supermarket, we asked "*Did you notice anything in the supermarket?*". When participants responded with yes, they could fill out what they noticed. When participants responded with no, it was explained that we changed something in the supermarket regarding marketing and signs, after which they could fill out again whether they had noticed anything. After this question and explanation, we also asked whether people thought the frames influenced their product choice (with the answer options yes and no).

[3] We also aimed to measure habitual decision-making experiences by asking "*Did you choose products that you usually choose?*". However, this question was deemed invalid as people were instructed to buy specific items possibly deviating from their habitually bought grocery items. Furthermore, the virtual supermarket had a limited array of options, potentially missing habitually bought items.

2.7. Control measures

VR supermarket experience. Realism of the VR supermarket was measured with the question "*How realistic did you find this virtual supermarket?*", ranging from *not realistic at all* (1) to *very realistic* (7) and ease was measured with the question "*How easy did you find shopping in this virtual supermarket?*", ranging from *very difficult* (1) to *very easy* (7).

Health importance. To measure whether participants considered healthy eating important, we asked "*How important is it to you to eat healthily?*", answered on a scale from 0 (*not at all important*) to 100 (*very important*).

Hunger. To measure how hungry participants were, we asked "*How hungry were you at the beginning of this experiment?*", answered on a scale from 0 (*not hungry at all*) to 100 (*very hungry*).

Alcohol consumption. Because the study was executed on a science festival during the evening hours, we measured alcohol consumption by asking "*How many glasses of alcohol did you have tonight?*" where people could fill out the number of glasses.

Demographic variables. Participants reported their age, sex and highest attained education level.

2.8. Statistical analyses

We first checked whether randomization across experimental conditions was successful by comparing the control measures of participants in the four different conditions, and whether the time pressure manipulation was successful by comparing participants in low vs. high time pressure conditions on the time pressure measures. Thereafter, we tested the main hypothesis that salience nudges would increase healthy food choices, and that this increase might show especially for individuals under time pressure by means of an ANOVA. We then explored whether nudging increases the total number of healthier food choices, either nudged or unnudged, by means of an ANOVA. Then, we explored whether nudging and time pressure might induce different decision-making experiences by means of cross-tabs. Lastly, we explored whether being aware of the nudges influenced nudge's effectiveness. In case one of the assumptions of the statistical tests was violated, the appropriate alternative test is reported.

In addition to the frequentist statistical tests, Bayesian analyses are performed when appropriate in order to quantify the evidence of the hypotheses under investigation given the data (Hoijtink, Mulder, Van Lissa, & Gu, 2019). When there was a specific expectation regarding the direction of an association, informative hypotheses are tested (Hoijtink et al., 2019). Bayesian Factors (BF) are reported, with a larger BF representing more evidence in the data set for the hypothesis under consideration. The descriptives of all measures are reported in table S1 and S2 in the supplementary materials.

3. Results

3.1. Randomization check

Separate one-way ANOVA's showed that there was no difference across the four experimental conditions regarding self-reported health importance ($p = .731$), hunger ($p = .285$), alcohol consumption ($p = .107$), age ($p = .974$), the ease of using the VR supermarket ($p = .631$), nor regarding how realistic ($p = .988$) participants found the VR supermarket to be. Similarly, a Fisher's exact test for education (Fisher's exact test, $p = .661$), and a Chi-square test for sex ($\chi^2(3) = 2.35$, $p = .504$), showed no differences across conditions, indicating successful randomization. See Tables S3 and S4 in the supplementary materials for the more detailed descriptives, Chi-square tests, and the specific one-way ANOVA results considering the randomization check.

3.2. Manipulation check

To assess the success of our time pressure instruction, three separate independent *t*-tests were performed with manipulated time pressure (low vs. high) as a predictor and subjective time pressure, subjective stress and objective time as dependent variables. As can be seen in Table 1, participants in the low vs. high time pressure conditions did not differ in their reported subjective time pressure or stress. Participants in the high time pressure condition did finish their shopping task marginally significantly faster than participants in the low time pressure condition.[4] The Bayesian independent samples *t*-test revealed that the data were somewhat more likely to reflect this difference based on time pressure condition, than for it to not reflect such a difference.

In order to further test the hypothesis that there was a meaningful effect of the time pressure manipulation on objective time spent, we resorted to equivalence testing (see Lakens, 2016). We defined the smallest effect of interest to be equivalent to a medium effect size of $d = 0.30$ (Cohen, 1988). A TOST independent samples *t*-test was run for the two time-pressure groups by use of the TOSTER package in R (Lakens, 2017). The lower bound was set to $d = -0.30$ and the higher bound to $d = 0.30$, with an alpha level 0.05. The equivalence test was not significant $t(97) = 1.96$, $p = .974$, while the null hypothesis test was significant, $t(97) = 1.99$, $p = .049$. This indicates that the time pressure manipulation indeed showed a meaningful effect on the objective time spent.

Thus, three pieces of converging evidence (independent samples *t*-test, Bayes Factor, and equivalence test) indicate that the time pressure manipulation successfully influenced participants shopping time.

Table 1
Comparing subjective and objective time pressure measures between the two time pressure conditions.

	High time pressure	Low time pressure	BF	*t*	*p*	*d*
	M (*SD*)	*M* (*SD*)				
Subjective time pressure	4.00 (1.55)	3.55 (2.00)	0.74	1.25	.216	.25
Subjective stress	3.34 (1.69)	3.18 (1.79)	0.31	0.45	.656	.09
Objective time spent	122.05s (42.74)	141.04 (51.74)	2.30	1.98	.051	.40

Note. BF = Bayesian Factor for the hypothesis that participants in the high time pressure condition experience more subjective time pressure or stress, and take shorter to shop, than participants in the low time pressure condition.

[4] Excluding one outlier with >3 *SD* above mean.

3.3. Main analysis: healthy nudged product choices

We performed a two-way ANOVA with time pressure (high vs. low) and nudges (present vs. absent) as between-subjects variables and healthy nudged product choice as dependent variable. There was a significant main effect of nudges, $F(1,95) = 6.41$, $p = .013$, $\eta_p^2 = 0.07$, but no main effect of time pressure, $F(1, 95) = 0.12$, $p = .728$, $\eta_p^2 = 0.00$, nor an interaction effect, $F(1, 95) = 0.644$, $p = .424$, $\eta_p^2 = 0.01$.[5] As can be seen in Table 2, participants chose more of the healthier nudged products in the nudges present condition compared to the nudges absent condition. A Bayesian independent samples *t*-test revealed that the data were 10.11 times more likely to reflect this difference based on nudges ($BF_{+0} = 10.11$), than for it to not reflect such a difference.

3.4. Healthier product choices, nudged or unnudged

We explored whether nudging could also increase the total number of healthier food choices, either nudged or unnudged, as a side effect of nudging one of the healthier food choices. We performed a two-way ANOVA with time pressure (high vs. low) and nudges (present vs. absent) as between-subjects variables and number of healthy options chosen as dependent variable. There was a significant main effect of nudges, $F(1,95) = 7.41$, $p = .008$, $\eta_p^2 = 0.07$. As can be seen in Table 3, participants chose more healthy options in the nudges present condition compared to the nudges absent condition. A Bayesian independent samples *t*-test revealed that the data were 10.12 times more likely to reflect this difference based on nudges ($BF_{+0} = 10.12$), than for it to not reflect such a difference. There was no main effect of time pressure, $F(1, 95) = 0.61$, $p = .438$, $\eta_p^2 = 0.01$, nor was there an interaction between nudges and time pressure, $F(1, 95) = 3.31$, $p = .072$, $\eta_p^2 = 0.03$.

This finding suggests that nudging healthier food options does not only increase choices of the explicitly nudged healthier options, but that it can also increase the total number of healthier food choices.

3.5. Decision-making experiences

We then examined whether being exposed to nudging and time pressure might be associated with different experiences regarding ones' decision-making process. We examined reflective as well as impulsive decision-making experiences.[6]

Reflective decision experiences. We first assessed whether there was an association between nudges (present vs. absent) and whether participants experienced their decision-making to be reflective (vs. not reflective). This showed not to be the case (Fisher's exact test, $p = .532$). A Bayesian cross-tabs revealed that the data were 3.05 times more likely to be observed under the null hypothesis ($BF_{01} = 3.05$), than for it to reflect a difference in reflective decision experiences based on nudge condition. Additionally, considering the possible effect of time pressure,

Table 2
Healthy nudged product choices for the four experimental conditions.

	Nudge *M* (*SD*)	No nudge *M* (*SD*)	Overall *M* (*SD*)
High time pressure	0.84 (1.11)	0.44 (0.51)	0.71 (1.28)
Low time pressure	1.08 (1.61)	0.33 (0.64)	0.64 (0.88)
Overall	0.96 (1.37)	0.39 (0.57)	0.68 (1.09)

[5] Including the participants that were excluded (who finished the shopping task, n = 9) did not change the results of this main analysis.

[6] 58.6% of the participants reported for only one of the types of decision-making to reflect their experience, 35.4% of participants reported more than one type of decision-making experience, while 6.1% reported for none of the measured experiences to reflect their decision-making experience.

Table 3
Healthier product choices, nudged or unnudged, for the four experimental conditions.

	Nudge *M* (*SD*)	No nudge *M* (*SD*)	Overall *M* (*SD*)
High time pressure	1.68 (1.11)	1.48 (1.01)	1.58 (1.05)
Low time pressure	2.24 (1.23)	1.25 (0.94)	1.76 (1.20)
Overall	1.96 (1.20)	1.37 (0.97)	1.67 (1.13)

no significant association showed between time pressure and reflective decision-making experiences, neither for participants who were nudged (Fisher's exact test, $p = .762$), nor for participants who were not being nudged (Fisher's exact test, $p = .387$). Hence, participants did not differ in likelihood of experiencing their decision-making as reflective based on the factors nudging and time pressure. For more detailed results of these analyses, see Table S5 in the supplementary materials.

Impulsive decision experiences. We assessed whether there was an association between nudges (present vs. absent) and whether participants experienced their decision-making to be impulsive (vs. not impulsive). This showed not to be the case (Fisher's exact test, $p = .837$). A Bayesian cross-tabs revealed that the data were 3.78 times more likely to be observed under the null hypothesis ($BF_{01} = 3.78$), than for it to reflect a difference in impulsive decision experiences based on nudge condition. Additionally, considering the possible effect of time pressure, no significant association showed between time pressure and impulsive decision-making experiences, neither for participants who were nudged (Fisher's exact test, $p = .769$), nor for participants who were not being nudged (Fisher's exact test, $p = .387$). Thus, participants did not differ in likelihood of experiencing their decision-making as impulsive based on the factors time pressure and nudges. For more detailed results of these analyses, see Table S6 in the supplementary materials.

3.6. Nudge awareness and healthy food choices

When participants were asked whether they had noticed anything in the supermarket, thirteen (26%) out of fifty participants in the nudges condition, reported to have noticed the nudges. A Welch's *t*-test showed that there was no significant difference regarding the number of nudged products chosen between participants who did ($M = 1.38$, $SD = 1.56$) or did not ($M = 0.81$, $SD = 1.29$) notice the nudge, Welch's $t(18.11) = 1.19$, $p = .248$. A Bayesian independent samples Mann-Whitney test revealed that the data were 2.28 times more likely to be observed under the null hypothesis ($BF_{01} = 2.28$), than for it to reflect a difference number of nudged products chosen based on nudge awareness. This finding suggests that consciously noticing the nudges does not necessarily undermine the effects of nudging.

After explaining the nudges to the participants in the nudges condition, the majority (60%) of participants in the nudge condition thought that the nudges did not influence their choice. Interestingly, a Welch's *t*-test showed that the participants (40%) who thought the nudges did influence their choice indeed chose significantly more nudged products ($M = 2.00$, $SD = 1.59$) than participants who thought the nudges did not influence their choice ($M = 0.27$, $SD = 0.52$), Welch's $t(21.74) = 4.71$, $p < .001$. A Bayesian independent samples Mann-Whitney test revealed that the data were 182.3 times more likely to reflect a difference between participants who did and did not think the nudges influenced their decision, than for the data to be observed under the null hypothesis ($BF_{10} = 182.3$).

4. Discussion

The main goal of the present study was to examine whether nudging increases healthy food choices in a supermarket environment, and whether this presumed effect would hold especially when people are under time pressure, a condition probing system 1 reasoning. In a VR supermarket experiment, healthy food choices were nudged (vs. a condition with no nudges), while participants were either under high or low time pressure when choosing their food items.

First of all, nudging showed to indeed increase the number of healthy food choices in the supermarket. This effect held for the healthy options that were being nudged, but also when considering both the nudged and unnudged healthier options. The fact that nudging increased healthy nudged food choices is in line with previous findings on nudging healthy food choices (e.g., Arno & Thomas, 2016; Broers et al., 2017; Bucher et al., 2016; Cadario & Chandon, 2020) and as such further confirms that nudging can increase healthy food choices in a supermarket environment. However, the side effect of nudging leading to a general increase in the total number of healthy food choices is, to our knowledge, a novel finding. In the current study design, all of the healthier options were positioned on either the left or right side of the shelves. Therefore, the most probable explanation for this finding is that even when a participant did not buy the exact nudged healthy product, the salience nudge did capture their attention and as such the products in proximity to the nudge stood out consequently (e.g., Breugelmans, Campo, & Gijsbrechts, 2007). This apparent proximity effect of nudging could be interesting to examine further related to healthy food choices in the supermarket. For example, it could be especially relevant to widen the scope of analyzed nudged purchases by including nearby products when considering the fact that healthier food choices - such as fruits or vegetables - are often presented in proximity to one another. Hence, future research could widen the scope of analyzed purchases due to nudging by incorporating the nearby product options as well.

Second, though it was expected that individuals under high time pressure would show stronger effects of the healthy food nudges, the effect of nudging on healthy food choice did not differ based on whether people were under low or high time pressure. Hence, our findings are not in line with the assumption of nudging being most effective under system 1 conditions where individuals are prone to apply faster and less deliberate reasoning.

Interestingly, participants in the high time pressure condition did not report to have subjectively experienced more time pressure or stress, but they did objectively shop faster. On the one hand, it would be possible that in order to induce system 1 reasoning, people need to subjectively experience time pressure and stress. Hence our inability to induce subjective time pressure and stress would render our system 1 reasoning manipulation insufficient. On the other hand, it is a well-documented finding that objective time is not isomorphic to subjective experienced or perceived time (e.g., Van Wassenhove, Buonomano, Shimojo & Shams, 2008; Matthews & Meck, 2016), and various factors have to date shown to influence subjective time perception. As participants in the high (vs. low) time pressure condition did choose their products faster, our manipulation did induce the expected behavioral differences. Furthermore, the fact that we did not find any difference in nudge effectiveness based on time pressure corroborates results of other studies that similarly report no difference in nudge effectiveness based on system 1 reasoning (e.g., Van Gestel, Adriaanse, & de Ridder, 2020), and studies showing that nudging can improve food choice irrespective of whether individuals are under system 1 conditions (e.g., Hunter et al., 2018). Indeed, the premise that nudges are primarily effective when individuals apply system 1 reasoning has recently been questioned (De Ridder, Kroese, & Van Gestel, 2020), and empirical evidence suggests that differences in the effectivity of nudging does not depend on an individuals' mode of thinking. Instead, empirical evidence suggests that nudges are effective if the option that is being nudged aligns with the nudged person's personal preferences, or if people are indifferent or hold conflicting preferences with respect to the given behavior (De Ridder, Kroese, & Van Gestel, 2020). For instance, the effect of a nudge on number of meat choices has been shown to be more pronounced for individuals experiencing conflicting feelings about eating meat (Venema, Kroese, Benjamins, & de Ridder, 2020) than for individuals that experience fewer conflicting feelings about eating meat. On the other

hand, nudges have shown to be ineffective when the nudged option goes against people's personal preferences (De Ridder, Kroese, & Van Gestel, 2020; Venema, Kroese, De Vet, & De Ridder, 2019).

All in all, the most plausible explanation for the fact that no difference in healthy nudged products purchases showed based on time pressure (high vs. low) appears to be that system 1 conditions are not required for nudges to be effective in supporting healthier choices.

Our results furthermore concur with research showing that being aware of the presence of nudges does not necessarily render them ineffective (e.g., Bruns et al., 2018; Kroese et al., 2016; Van Gestel et al., 2018). In the current study, when asked if they had noticed anything in the supermarket, only 26% of participants in the nudge condition mentioned to have noticed the nudge. Nudging showed to be equally effective for participants who had and who had not noticed the nudge. Moreover, after having received the explanation regarding the nudges to which they had been exposed, the majority of participants thought that the nudges had not influenced their choices (for similar results, see Kroese et al., 2016). Interestingly though, participants who thought the nudges had influenced their choices showed to have indeed chosen more nudged products. Though speculative, it does suggest that even though participants might not have been aware of the nudges consciously during their shopping experience, in hindsight they did register and remember having bought the nudged products. In combination with the effect of nudging on participants who reported to notice the nudge, this further supports the idea that people do not necessarily have to be unaware of nudges for them to be effective (De Ridder, Kroese, & Van Gestel, 2020).

With respect to participants' decision-making experiences, these showed to be similar under all experimental conditions. Though a null finding, it does provide insight into the effect of nudging on decision-making experiences, suggesting that being nudged might not affect whether a person experiences their decision making as impulsive or reflective. However, in the current study binary measures to measure decision-making experiences were used post-test. It might be more informative for future research to assess more thoroughly to what extent different decision-making experiences are present (e.g., by use of multiple questions per decision-making experience, as well as by using a Likert scale) in order to provide a more realistic representation of decision-making experiences under nudge conditions.

Besides the use of binary measures for decision-making experiences, it would be relevant for future research to further examine the influence of system 1 conditions on the effectiveness of nudges on healthy food choices. In the current study we have used time pressure as a proxy for a system 1 condition. The influence of system 1 conditions on the effectiveness of nudging healthy food choices could be explored further by use of other system 1 proxies such as by inducing cognitive load (e.g., as in: Van Gestel et al., 2020). Furthermore, in the current study we did not examine the effect of system 2 conditions on the nudge effectiveness. Even though individuals in the low time pressure condition can be assumed to have had the opportunity to employ more system 2 reasoning compared to individuals in the high time pressure condition, this was not explicitly tested. Examining the effectiveness of nudging healthy food choices under conditions stimulating system 2 reasoning, for example by explicitly instructing individuals to deliberate upon their (food) choices (as in: Van Gestel et al., 2020) or by instructing them to reason deductively (Evans, Handley, Neilens, & Over, 2010). Given the fact that the use of system 1 versus system 2 reasoning is generally used as a base to explain the working of nudging, it would be important to explicitly examine these bases. This would first of all advance the understanding of the psychological premises underlying the working of nudges, while further knowledge on the underlying mechanisms of nudging would also provide the opportunity to design more effective nudges. Lastly, even though research shows that purchases in virtual reality supermarkets resemble those made in physical supermarkets (Waterlander et al., 2015), it would be valuable to replicate the current study in a physical supermarket.

The present experiment adds to the current empirical evidence on the possible influence of contextual elements on the effectiveness of nudging healthy food choices. The findings extend previous work on nudging healthy food choices by combining elements of realistic field studies, in a relatively controlled experimental setting by using a realistic virtual reality supermarket environment. All in all, our findings show that a salience nudge can increase healthy food choices in a supermarket environment, and that this effect is not dependent on whether individuals are under high or low time pressure. This is in line with recent viewpoints on the premises of nudges, suggesting that alleged system 1 conditions are not a prerequisite for nudging to be effective.

Author contributions

FDB, MG and DTDDR designed the study. NVDL designed the virtual supermarket environment. FDB collected the data and prepared the data for analyses. SSAHB drafted the first version of the manuscript, MG and DTDDR revised and contributed towards the further and final version. All authors read and approved the final manuscript.

Funding

This work is part of the Supreme Nudge (CVON 2016–04) project and is supported by the Netherlands Heart Foundation and the Netherlands Organization for Health Research and Development (ZonMw). These funding sources had no role in the design of this study, the data collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Data availability statement

A data set is available and stored and access can be requested from the corresponding author if needed.

Ethical statement

The study was approved by the Ethics Review Board of the Faculty of Social and Behavioral Sciences at Utrecht University. Participants signing an informed consent before taking part in the study.

Declaration of competing interest

None.

Acknowledgements

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2021.105116.

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