An Experimental Analysis Of Non-acting and Acting Cues:
Using The Automated Operation Span Task To Assess Light Regulation As Energy Saving

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Abstract

In 2015, the Paris Agreement emerged as a global initiative from the notion that contemporary environmental challenges are caused by unsustainable patterns of human activity. Subsequent behaviour change interventions were focused on promoting individual pro-environmental behaviours from a rational-actor paradigm. They viewed behaviour is determined by reasoned choices, motivation, and conscious intent. Many cases of energy consumption behaviours that are ought to be changed are rather habitual. Their formation serves an adaptive purpose of reducing demand on one's attention and memory processing and may then lead to stubborn patterns of behaviour that are hard to change. One such example concerns non-acting habits, whereby individuals refrain from performing an energy saving action because it became part of their behavioural routine. The present study sought to explore the effects of frequent non-acting for energy saving action omitted in an adapted version of the Automated Operation Span Task. 73 Participants took part in the online experiment. The results indicated that there was no difference between frequent and less frequent non-acting for the amount of energy saving actions omitted. Instead, the current research offers a challenge for the rationale behind pro-environmental behaviours. Future research is addressed, and the newly developed paradigm is discussed.

Keywords: pro-environmental behaviour, Automated Operation Span Task, non-acting, acting, habitual behaviour

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The Paris Agreement emerged in 2015 as a global initiative from efforts made by policymakers and governments to agree on internationally binding climate targets. As a result, 196 countries set out a framework to combat climate change by having each one of the involved parties submitting plans addressing their intentions to adapt, avoid, or cope with global warming (Rogelj et al., 2016). This led to the Dutch National Climate Agreement in the Netherlands, whereby the central goal of reducing greenhouse gas emissions was divided into climate policy objectives for five sector platforms: built environment, mobility, industry, agriculture and land use, and electricity (Rijksoverheid, 2019). Two measures that have already been implemented concern the reduction of the maximum speed allowed for cars on motorways during daytime from 130 kilometers to 100 kilometers per hour in order to help reduce the Dutch nitrogen-problem, and the built of offshore wind farms to develop a carbon-free electricity system (Rijksoverheid, 2019).

Since it is becoming increasingly clear that contemporary environmental challenges, like climate change and global warming, are caused by unsustainable patterns of human activity, it seems illogical that the Climate Agreement does not address household energy consumption as one of their sectors with corresponding climate objectives. Research suggests that 72% of global greenhouse gas emissions stems from household energy consumption, with the remainder coming from public and non-governmental and financial sources (Dubois et al., 2019). Most people are not in positions of power where they can directly influence governmental or corporate policy, but all people consume energy and materials in their daily lives, and as such, each individual can choose to adopt behaviours that are comparatively better for the environment (Osbaldiston & Schott, 2012). It is therefore important to explore what factors underly frequently expressed household energy consumption behaviours, so that behaviour change interventions can be designed to promote individual pro-environmental behaviours.

Rational-actor paradigm

These pro-environmental behaviours are referred to as the action's individuals express by consciously seeking to minimize the negative impact of one's behaviour on the natural and built world (e.g., minimize resource and energy consumption, use of non-toxic substances, reduce waste production) (Kollmuss & Agyeman, 2002). The majority of studies that have investigated the psychological mechanisms that lead people to express pro-environmental behaviours (e.g., Abrahamse & Steg, 2009; Bamberg & Möser, 2007; Heath & Gifford, 2002; Lynne et al., 1995; Taylor & Todd, 1995) use Azjen's (1991) theory of planned behaviour as their theoretical framework. The theory of planned behaviour assumes that intentions are the most proximal predictors of behaviour, which in turn are determined by attitudes, perceived behavioural control, and subjective norms (Azjen, 1991). Behaviour change interventions developed from this perspective therefore focus on the antecedents and consequences of pro-environmental behaviours, or removing barriers towards them (Abrahamse et al., 2005). By providing rewards or offering feedback, the goal is to promote individual pro-environmental behaviours by changing the underlying attitudes, intentions, and motivations for energy consumption behaviours. This is referred to as the rational-actor paradigm within pro-environmental behaviours literature (Maréchal & Holzemer, 2015), where social change is thought to depend upon values and attitudes, as they are believed to drive the kinds of behaviour that individuals choose to adopt (Shove, 2010).

Habitual behaviours

However, climate targets agreed on during the Paris Agreement will not be met when behaviour change interventions from the rational-actor paradigm target behaviour that occurs without much deliberative reasoning or conscious intent. In many cases of household energy consumption, behaviour is habitual and guided by automated cognitive processes (Steg & Vlek, 2009). Habits are referred to as the phenomenon whereby behaviour persists because it has become an automatic response to a particular, regular encountered, context that is acquired through associative learning (Kurz et al., 2015). One example concerns indoor light regulation. By repeatedly and satisfactorily performing a behaviour, like turning on the lights when entering a dark room, a mental context-behaviour-response-association is formed. When this behaviour is frequently expressed in the same environmental context, the mental association becomes more accessible and grows stronger (Kurz et al., 2015). After sufficient pairings of these context-behaviour associations, entering a dark room is thought to automatically activate the response of turning on the light. Subsequent successful habitual performances strengthen these associations, leading to pass over behavioural control from conscious deliberation to the automatic activation of routines by external cues (Gardner et al., 2011).

Behavioural sequences

Most patterns of frequently expressed household energy consumption behaviours do not merely consist of singular actions. Rather, they occur simultaneously with other behaviours during a sequence. For instance, turning off the light upon leaving a room is preceded by getting up from the place one’s seated, walking toward the door and pressing the light switch, followed by closing the door on the way out. With repetition, the behaviours that precede and follow turning off the light that are embedded in the behavioural sequence are just as likely to become automated as the focal act itself (de Vries et al., 2011). In this view, habits are conceived as mere components in a sequence of ‘if-then’ links, which then may be compiled into one procedural instance when the sequence is frequently expressed (Mittal, 1988). For instance, if an individual opens the car door, he or she will sit down behind the wheel, followed by the action of buckling up as the individual is seated, starting the engine and driving off. By frequent repetition, the actions of entering the car to drive off can thus be encapsulated in a larger behavioural unit in which the actions are inextricably bound (Aarts et al., 1997; Bargh, 1990; de Vries et al., 2011; Triandis, 1979; Verplanken & Aarts, 1999).

Non-acting habits

The reasoning behind habit formation may not only apply to habitual acting, but also to habitual non-acting for instances were individuals refrain from performing an action as part of a behavioural routine (de Vries et al., 2011). Referring back to Mittal's (1988) example, people that frequently omit using their seatbelt when driving might lead to a habit of not buckling up after sufficient parings. The sequence of actions in 'if-then' links then differs from the first as to *not* fastening your seatbelt when sitting down behind the wheel and starting the car, leading to the same behavioural sequence with opposing behaviours. Neglecting to turn off the lights when leaving an unoccupied room, leading to increased household energy consumption, may be an example of non-acting behaviour encapsulated in a behavioural sequence, leading to a non-acting habit when learned as an automatic response to a frequently encountered stable context. Thus, the difference between a non-acting and acting energy saving habit may rest on the notion that both are incorporated into a behavioural sequence of 'if-then' links, in which the focal act is omitted in the first (de Vries et al., 2011).

Cognitive efficiency

The formation of habitual behavioural patterns serves an adaptive purpose by reducing demand on one's attention and memory processing. This cognitive efficiency, however, may in turn lead to stubborn patterns of energy consumption that are hard to change. As argued by Gardner et al. (2011), where habits and intentions conflict, behaviour is more likely to proceed in line with habits because they act like a barrier for intentions to lead to action. Habits override deliberative intentions because they are triggered directly and immediately by their associated contexts. As such, the process of habit formation can interfere with people changing their behaviour in response to new information, as information changes their attitudes and intentions, but not their behaviour, which is triggered by the associated context (Gabe-Thomas et al., 2014).

Dual-process theory

The question of why individuals sometimes behave habitual and otherwise engage in deliberate processing can be explained by dual-process theories of the mind. They argue that behaviour is determined by the interplay of automated and controlled processing, whereby automatic processing is responsible for the selection of routine thoughts or habitual actions (Barrett et al., 2004). It is assumed to be the default mode of processing and occurs through environmental cues grasping our attention. For instance, an unoccupied room may act as cue for the habitual expression of turning off the light, once an individual has perceived the context and stored this situation in memory after repeated and sufficient pairings. When there are many stimuli present in an environment, different cues may be perceived simultaneously and compete for their own expression. In those circumstances, strength of the learned cognitive structure determines which cue leads to behavioural expression (Barrett et al., 2004).

When the selected behaviour is incorrect or inappropriate for the situation or task at hand, attention must be controlled to resolve conflict between a representation that is inconsistent with processing goals, or when two goals are in conflict with one another (Barrett et al., 2004). For example, a formed habit of not turning off the light when leaving an unoccupied room may interfere with one's goal of saving household energy. In such circumstance, allocating attention is required to deliberately enhance the goal of household energy saving, or to inhibit the non-acting habit cue. As such, controlled processing is responsible for overcoming the degree to which automated processing influences behaviours, feelings, and thoughts (Barrett et al., 2004).

Working memory capacity

The defining difference between automatic and controlled processing resides in their dependency of working memory; the cognitive system that involves the active storage, maintenance, and manipulation of information (Baddeley & Hitch, 1974). Working memory is active when task goals need to be actively maintained in order to override an automatic routine, or when information that could not be actively maintained needs to be retrieved from memory (Unsworth & Engle, 2007). Daily routines, such as remembering to turn off the lights when leaving an unoccupied room, can almost effortlessly be retrieved from memory and requires few cognitive operations and reliance on working memory. Therefore, automatic processing allows one to continue with subsequent parts of the behavioural routine, like simultaneously taking off your coat and shoes. In contrast, when one receives an important phone call from work that needs to be remembered, while simultaneously entering the room and following subsequent parts of the behavioural routine, accessibility of the message decreases. This is especially the case when there is no active maintenance on remembering the message. Hence, working memory is engaged with keeping information active and in a quickly retrievable state by providing and controlling attention toward it (Engle, 2002).

The capacity of working memory to engage in controlled processing is limited, meaning that there is a restriction on the amount of information that individuals can keep active at any given time (Strack & Deutsch, 2004). When it is not possible to actively maintain information, working memory is involved with retrieving information from long- and short-term memory. Retrieving this information often occurs in the presence of irrelevant information that interferes proactively with relevant information (Unsworth & Engle, 2007). For instance, information associated with entering the room is not relevant for remembering the message from work. Because this information is usually relevant when you do not have the task goal of remembering the message from work while following the behavioural routine, it competes for access with currently relevant information. Accordingly, individuals need to be able to correctly discriminate between relevant and irrelevant information in regard to their current task goal. This discrimination process relies on motivation and opportunity (Barrett et al., 2004), and a combination of cues, particularly contextual ones, as the current situation determines what information is relevant or irrelevant in order to be correctly retrieved (Unsworth & Engle, 2007).

Complex span tasks

Working memory capacity can be assessed by having individuals perform complex span tasks. They are designed in such a way that the executive attention of working memory is engaged by keep some information active and quickly retrievable, while periodically shifting attention to some secondary processing task under time pressure (Baddeley & Hitch, 1974). Moreover, they represent how well the accessibility of representations is managed by attentional control in situations in which there is an interference or distraction (Barrett et al., 2004). The Operation Span Task (Ospan; Turner & Engle, 1989) is an example of such a complex span task, whereby participants are instructed solve a series of math operations while trying to remember a set of unrelated words. When the operation-word string ‘IS (6 : 2) – 2 = 2 ? DOOR’ is presented, participants first read the operation, respond as to whether or not the equation is correct and then read the word aloud. After a predetermined series of operation-word strings, participants have to recall the list of presented words. The total number of correctly recalled words is then calculated and serves as a measure of working memory capacity (Turner & Engle, 1989).

As working memory capacity is involved with actively maintaining goal-related information active in order to guide response selection (Redick et al., 2007), complex span tasks can be used to simulate the automated and controlled processes that underly a behavioural sequence. Periodically shifting between processing-and-storage causes interferences and a challenge for individuals to make efficient use of their attentional control. This is comparable to the example where attention was needed to be allocated to the important message from work while following the behavioural sequence of entering the room, or the example where it was necessary to override the non-acting habit cue to achieve the goal of energy saving. These instances all occurred under time pressure, making it necessary for the cognitive system to adapt accordingly. When individuals are motivated and able to engage in deliberate goal pursuit, they might set and initiate behavioural intentions to develop pro-environmental behaviours. Nonetheless, many instances of household energy consumption behaviours arise through cues that generate action with little conscious monitoring,

Aim of the present study

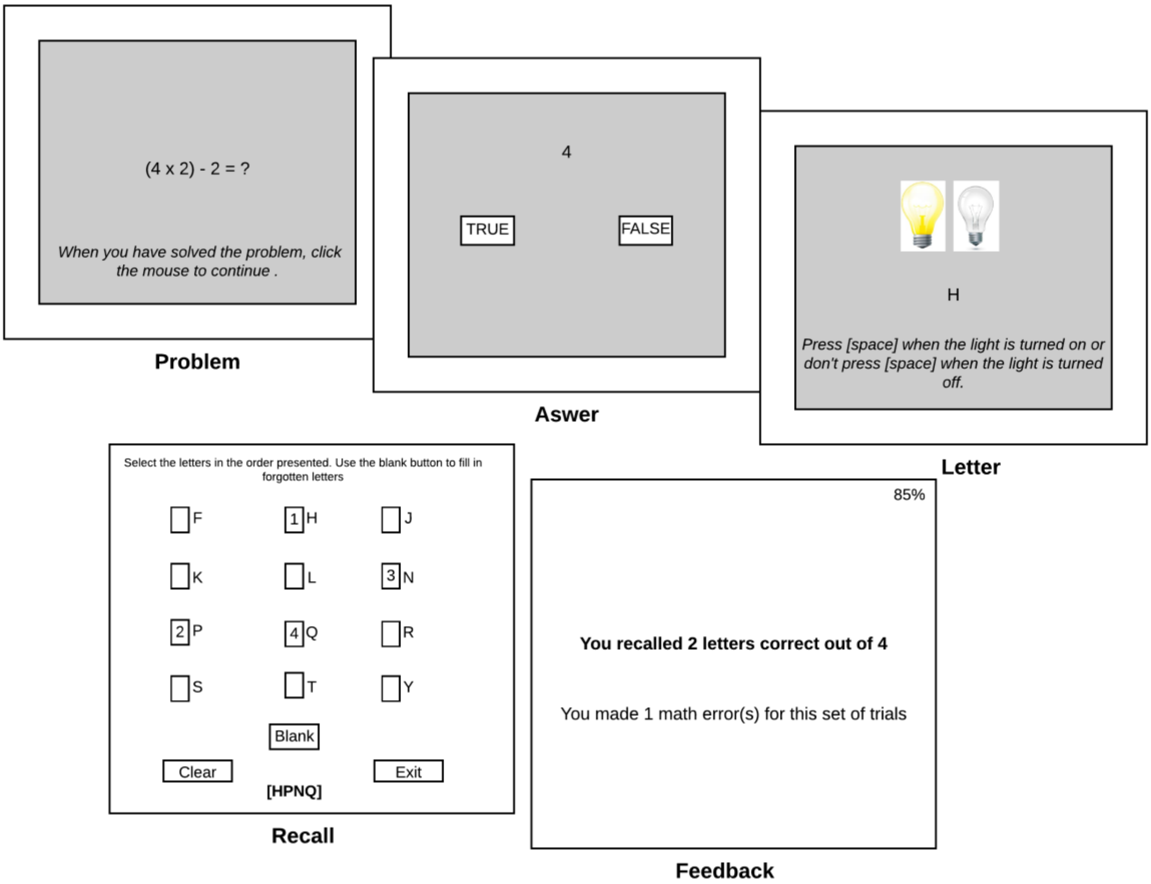
Experimental studies focusing on the habitual character of frequently expressed behaviours are scarce within the pro-environmental behaviours literature. It is therefore that the present study will contribute to this area of research by analysing whether behaviour change in a context of participants acting upon energy saving cues that were previously frequent non-acted upon, is more difficult than when these contextual cues are less frequently linked to non-acting.

Participants in the present study are going to perform an adapted version of the Automated Operation Span Task (Aospan: Unsworth et al., 2005) (Figure 1). This task involves a dual-task action setting, whereby the regular Aospan task is combined with light regulation. The combination of these tasks requires participants to actively alternate between an active behavioural measure and information processing-and-storing, thus simulating the interferences that occur when a behavioural sequences conflicts with task goals. Previous research suggests that reaction times increase, or accuracy decreases when participants change between different task configurations (Alport et al., 1994; Sigman & Dehaene, 2006). By combining the Aospan task with light regulation, it will be expected that participants' performances decrease when both tasks are combined.

Moreover, the consequences of frequent non-acting upon energy saving cues before acting upon acting cues will be explored by the amount of action omissions participant make after non-acting upon energy saving cues. Action omissions are errors made during routine sequential actions despite having a lack of intention to omit them (Reason, 1990; Trafton et al., 2011), and can account as a measure for failures in behaviour change. Subsequently, frequency will be assessed by manipulating the number of instances that participants have to non-act during the Aospan-task. It will be expected that participants in the high frequent non-acting condition will have a larger number of action omissions than participants in the low frequent non-acting condition. Finally, it will be expected that participants with a lower Aospan-score in the high frequent non-acting condition will have a larger number of action omissions than participants in the low frequent non-acting condition with a higher Aospan-score.

Figure 1

Outline of one trial in the adapted Aospan task. The first three screens show one processing- and storage sequence and the last two show the recall and feedback screens.



Method

Participants and design

A g*power analysis (Faul et al., 2007) that was based on the effect size provided by the study of de Vries et al. (2011) (Appendix 1 and 2) estimated that 81 participants would provide a sufficient sample size for the present study. 90 Participants were recruited to take part in the experiment. However, some datasets were excluded due to not reaching an imposed accuracy criterion (mean math accuracy < 85%), zero value for the Aospan task during the first test phase, and 100% action omissions made during the second test phase. This led to analysing the responses of 73 participants, of which 42 were women. Their ages ranged between 19 and 70 years old (*M* = 26.26; *SD* = 11.12). Participants were selected via the personal network of the researcher, social media, and the Social and Behavioural Sciences research participation system of Utrecht University. Students from this university were eligible to receive research credit for their participation, however, no monetary compensation was given. Participants were sequentially divided into one of two conditions as the experiment contained a between subjects' design (*low* versus *high* non-acting frequency). The independent variables were individual Aospan-scores for the non-acting and acting test phases, frequency condition, and the latency of acting responses. The dependent variable was the number of action omissions made by participants.

Procedure and materials

Participants were invited to participate via a link to the online survey platform Qualtrics. Here they were provided with an information letter about the study and asked for their consent. After providing consent, participants were redirected to the launch page of Inquisit Player 6 were they could start with the Aospan task. Participants were then notified about the importance of either using a mouse or trackpad and not being disturbed while performing the task. Subsequently, instructions about the trials and blocks were presented. For each trial in the Aospan task, participants saw a math equation they had to solve in their mind, followed by clicking the mouse to proceed to the next screen where an answer for the equation and a true and false box was presented. After indicating whether it was correct, a letter and light bulb cue were presented on screen for 800 milliseconds. Participants had to remember the letter for later recall. After three to seven of such processing-and-storing sequences, a recall grid of 4 x 3 letters (F, H, J, K, L, N, P, Q, R, S, T, and Y; Unsworth et al., 2005) was presented with boxes next to them in order to tick the correct serial order of the presented letters. Accuracy feedback about the recall part was then given by the computer, before progressing to the next processing-and-storing presentation. This process continued until the amount of the letters of a particular set size was met. These set sizes were randomized across trials and differed in having 3 to 7 letter presentations. Each set size was presented three times, making a total of 75 letters to remember and 75 equations to solve in each test phase. The practice blocks differed from these as to only having two set sizes presented twice. In total, there were four practice blocks and one non-acting and acting test phase.

Before proceeding to each new block, participants received instructions explaining what would be expected of them in the following trials. During the first block, participants started with practicing the letter part by having letters presented and recalling them in correct serial order. The second block was used to practice with the math part of the task. Participants were instructed to solve 15 math equations as quickly and accurately as possible. Afterwards, the computer calculated the mean time required for each participant to solve the equations. This time plus 2.5 SD was then used as a time limit for solving the equations in further blocks (Unsworth et al., 2005). If participants took more time than their time limit, the computer automatically moved on and counted that trial as an error. The third practice block was a combination of both parts of the task. During this block, participants were notified of a percentage in red in the upper right-hand corner of the recall accuracy screen. This percentage was an indication of the amount of math equations solved correctly and was used to encourage participants to be equally focused on both parts of the task. They were instructed to keep this percentage at or above 85% at all times (Unsworth et al., 2005).

Participants then progressed to the non-acting test phase. Here they were deliberately notified of the light bulb cue that accompanied the letters and received an instruction to keep in mind how often the light bulb would be turned on during subsequent trials. This test phase remained otherwise equal to the processing-and-storing sequence. When participants finished this test phase, a survey question was presented that would later on serve as the manipulation check. Subsequently, instructions were provided for the last practice block and test phase.

Participants were now instructed to act upon the light bulb cue for the remainder of trials by pressing the spacebar in order to turn the light off when a turned-on light bulb was presented. To simulate their acting on the instruction, a turned off light bulb was presented right after participants had pressed the spacebar. Finally, participants had completed the Aospan task and were redirected to Qualtrics in order to answer questions regarding their aim, motivation, and effort during the Aospan task. They were also asked to indicate their age and gender. After filling in the survey questions, participants were thanked and debriefed. In sum, the study took about 45 minutes to complete.

Aospan task. The Aospan task by Unsworth et al. (2005) is an automated version of the Ospan task by Turner and Engle (1989) and was used for this study due to its good internal consistency (α = .78) and test-retest reliability (α = .83). The Aospan task is entirely mouse driven, does not rely on the experimenter to be administered and can be adapted for experimental purposes. Inquisit 6 was used to modify the script for the present study (Millisecond Software, 2010). At the end of the task, five scores are reported. The Aospan values are scored with the traditional absolute scoring method as the sum of all perfectly recalled sets. Moreover, the total number of correctly recalled letters, math errors, speed errors, and accuracy errors are measured.

Cues. Two light bulb pictures were used as a cue for non-acting or acting during the acting test phase (Appendix 3). These light bulbs differed in being turned on or off, and one of both were presented simultaneously above the letter during the processing-and-storing sequence of a trial.

Frequency. Frequency was assessed by manipulating the percentage of trials in which the light bulb was turned on or off. During the low-frequency condition, participants saw a light bulb turned off in 80% and turned on in 20% of the sets during the non-acting test phase. This distribution was switched around for the high-frequent non-acting condition, having a light bulb turned on for 80% and off for 20% of sets in the non-acting test phase. This high-frequent distribution was also used for the light bulb presentations in the acting test phase.

Action omissions. The amount of times that a participant did not press the spacebar to turn the light off during the acting-block when they should have pressed the spacebar, were counted as action omissions.

Manipulation check. A manipulation check was incorporated to determine whether participants were aware of the number of instances that they had non-acted during the non-acting test phase. After this phase, participants were asked to indicate on a 5-point Likert scale (from 1 = ‘0%’ to 5 = ‘100%’) how often they thought that the light bulb was turned on during the previous trials.

Survey questions. Participants answered nine questions regarding their aim, motivation, and effort for the different parts of the task. The first three question were answered by indicating on a 5-point Likert scale (from ‘Extremely aimed’ to ‘Extremely unaimed) to what extend they aimed to turn all the light bulbs off and get all math equations and letter recall correct. Subsequent questions asked participants to indicate the extent of their motivation (from ‘Extremely motivated’ to ‘Extremely unmotivated’) and how much they made an effort (from ‘Extremely effortful’ to ‘Extremely effortless) for each of these three parts in the Aospan-task.

Data-analysis

Participant responses and scores were recorded in Inquisit 6 and Qualtrics and exported to SPSS Statistics 26.0. Data from the Aospan task was then changed from a long to a wide file by computing the mean values of participants’ math accuracy values and the mean latencies of the acting responses. The maximum values of the Aospan task were used, as the script was written in such a way that it would automatically add up participants’ scores. The non-acting and acting Aospan scores were then calculated as z-scores. Subsequently, action omissions were calculated as a percentage, dividing the number of omissions by the amount of times participants could turn off the light during the acting test phase. The survey questions were then recoded from 1 (Extremely aimed, motivated, effortful) to 5 (Extremely unaimed, unmotivated, effortless). A missing value analysis was than performed, but no missing values were present. Reliability analyses were conducted and showed a sufficient internal consistency for the math (Cronbach's alfa = .652), letters (Cronbach's alfa = .738) and light (Cronbach's alfa = .708) parts of the Aospan task.

The resulting data were explored by testing whether the assumptions for conducting an independent samples *t* test, one-way ANOVA, repeated measures ANOVA and one-way ANCOVA were met. Examination of the Shapiro-Wilk statistic indicated that the assumption of normality was violated for all analyses. Inspection of the skewness and kurtosis suggested that the distribution of scores were normal for both frequency conditions and Aospan-scores in both test phases. Moreover, the central limit theorem argues that the assumption of normality can be assumed regardless of the shape of the sample data when the sample size is greater than 30 (Field, 2013; Lumley et al., 2002). Thus, the violation was accepted for all analyses. Levene's test was significant for the independent samples *t* test, indicating that equal variances could not be assumed. However, Levene's test was not significant for the one-way ANOVA and ANCOVA. The assumption of homogeneity of variances for the repeated measures ANOVA was examined by calculating the *F*MAX = 1.042, demonstrating that it was accepted. Moreover, Mauchly's test indicated that the assumption of sphericity was not violated. Finally, scatterplots indicated that the relationship between the covariate (Aospan-score non-acting test phase) and the dependent variable (action omissions) was linear and the assumption of homogeneity of regression slopes was supported by the absence of a significant IV-by-covariate interaction, $F(1, 69) = 2.32$, $p = .132$, for the one-way ANCOVA.

Results

Manipulation check

An independent samples *t* test was used to compare participants' estimates of how often the light bulb was turned on during the non-acting trials by participants in the low-frequency condition ($N = 40$) to the amount of times as reported by those in the high-frequency condition ($N = 33$). Participants in the low-frequency condition should have reported that the light bulb was turned on in 25% of the trials, and participants in the high-frequency condition 80%, as these answers were the closest to the true answers of 20% and 80%. The *t* test was statistically significant, with participants in the low frequent non-acting condition ($M = 2.25$; $SD = .63$) reporting that the light bulb was turned on less often than participants in the high frequent non-acting condition ($M = 3.24$; $SD = .75$), $t(63) = -6.035$, $p = .000$, two-tailed, $d = 1.20$, indicating a large effect (Cohen, 1988).

Main analyses

Subsequently, table 1 shows the descriptive statistics for the measures used in the analyses. A one-way between groups ANOVA has been conducted to analyse whether participant in the high frequent non-acting condition made more action omissions than participants in the low frequent non-acting condition. The analysis showed that participants in the low frequent non-acting condition ($M = 11.19$; $SD = 8.82$) made more action omissions than participants in the high frequent non-acting condition ($M = 10.83$; $SD = 7.34$), but this result was not statistically significant, $F(1, 71) = .035$, $p = .853$, and contrary to previous expectations.

Table 2

Descriptive statistics for the Aospan task.

	M	SD	Range
Non-acting			
Aospan score	42.55	15.17	6 - 75
Total sets recalled	9.51	2.82	2 - 15
Total correct letters	58.96	10.11	20 - 75
Math correct	70.82	2.54	65 - 75
Math errors	4.18	2.54	0 - 10
Speed errors	1.34	1.08	0 - 4
Accuracy errors	2.84	2.36	0 - 9
Acting			
Aospan score	44.74	15.81	0 - 70
Total sets recalled	9.86	3.07	0 - 14
Total correct letters	60.18	12.25	9 - 74
Math correct	71.68	2.60	63 - 75
Math errors	3.32	2.60	0 - 12
Speed errors	.47	1.26	0 - 9
Accuracy errors	2.85	2.31	0 - 11
Action omissions*	6.64	4.92	0 - 18

Note. *N* = 73, M = mean, SD = standard deviation, *percentage

Moreover, a Repeated Measures ANOVA was conducted to analyse whether participants' Aospan-scores would be lower in the acting test phase compared to the non-acting test phase. Results from the ANOVA showed the opposite effect of what was expected, with participants scoring lower during the non-acting phase (*M* = 42.55; *SD* = 15.17) than the acting phase (*M* = 44.74; *SD* = 15.81), but this effect was not statistically significant, $F(1, 72) = 2.16$, $p = .146$.

A one-way ANCOVA was then used to compare participants in the low- and high-frequent non-acting conditions for the amount of action omissions made, after controlling for the effects of Aospan-scores during the non-acting test phase. The ANCOVA indicated that participants' scores in the non-acting test phase were statistically significant related to the amount of action omissions made, $F(1, 70) = 7.85$, $p = .007$, partial $\eta^2 = .101$, which implies that better performances on the Aospan task in the non-acting test phase resulted into making more action omissions during the acting test phase. However, after controlling for the effects of non-acting Aospan-scores, there was no statistically significant effect of participants' frequency condition predicting the amount of action omissions participants made in the acting test phase, $F(1, 70) = .086$, $p = .770$. This result was not in accordance with the expectations.

Exploratory analyses

Exploratory analyses were then conducted to provide a better understanding of the unexpected findings. A one-way ANOVA was used to compare the low- and high-frequent non-acting conditions for their aim, motivation, and effort towards turning off the light during the acting test phase. The analysis showed that participants in the low-frequent non-acting condition were less aimed ($M = 2.25$; $SD = 1.10$) than participants in the high-frequent non-acting condition ($M = 2.48$; $SD = 1.06$), but this effect was not statistically significant, $F(1, 71) = .846$, $p = .361$. Also, participants in the low-frequency condition ($M = 1.98$; $SD = .73$) were less motivated ($M = 1.98$; $SD = .73$) than participants in the high-frequency condition ($M = 2.48$; $SD = .94$). This difference was statistically significant, $F(1, 71) = 6.78$, $p = .011$, indicating that participants in the high-frequent non-acting condition were more motivated for turning off the light in the acting test phase. Participants in the low-frequent non-acting condition also reported being less effortful ($M = 2.03$; $SD = .86$) than participants in the high-frequent non-acting condition ($M = 2.15$; $SD = .76$), but this difference was not statistically significant, $F(1, 71) = .435$, $p = .512$.

Finally, a one-way ANCOVA has been conducted to compare participants in the low- and high-frequent non-acting conditions for their Aospan-scores of the acting test phase. A covariate was included to control for the effects of participants' Aospan-scores in the non-acting test phase. The ANCOVA indicated that participants' Aospan-scores in the non-acting test phase were statistically significant related to participants' scores in the Acting test phase, $F(1, 70) = 52.85$, $p < .001$, partial $\eta^2 = .430$, which implies that scoring higher on the Aospan task in the non-acting test phase predicts better performances on the Aospan task during the acting test phase. However, after controlling for the effects of Aospan-scores in the non-acting test phase, there was no statistically significant effect of participants' frequency condition on participants' scores in the Acting test phase, $F(1, 70) = .000$, $p = .982$.

Discussion

The present study sought to explore whether behaviour change in a context of participants acting upon energy saving cues that were previously frequent non-acted upon, was more difficult than when these contextual cues are less frequently linked to non-acting. An experiment has been conducted whereby the Aospan task was combined with light regulation, thus creating a dual-task action setting. It was expected that this would lead to a decrease over time in participants' working memory capacity as measured by their Aospan-scores, because switching between task configurations is assumed to decrease accuracy and therefore lesser performances. Moreover, it was expected that frequent non-acting would lead individuals to omit more energy saving actions than less frequently non-acting participants. Finally, it was expected that participants which frequent non-acted and measured a lower working memory capacity, would lead to omitting more energy saving actions than participants that non-acted less frequently with a higher capacity for working memory.

Findings

The manipulation check showed a significant difference between estimates of participants that frequent non-acted and non-acted less frequently, indicating that participants noticed a difference in how often the light bulb was turned on during the non-acting test phase. However, results from the main analyses indicated that there was no significant difference between frequent and less frequent non-acting for energy saving actions omitted, as participants made on average less action omissions after frequent non-acting than participants that non-acted less frequently. Furthermore, the results showed that there was no significant difference for participants' working memory capacity scores during non-acting and the dual-task action setting. In fact, this led to a small increase on average. Moreover, the results showed that participants' working memory capacity scores during non-acting were related to the number of energy saving actions omitted, meaning that better performances in the first test phase predicted more action omissions in the second. After accounting for non-acting working memory capacity scores, there was no difference between the amount of actions omitted between participants with a lower working memory capacity that frequently non-acted, and participants with a higher working memory capacity that non-acted less frequently.

The exploratory analyses indicated that participants' self-reported level of motivation for turning off the light during the acting test phase differed significantly between the high- and low frequent condition. After frequent non-acting, these participants omitted less energy saving actions on average and indicated that they were more motivated for turning off the light than participants that non-acted less frequently. However, there was no significant difference between participants that non-acted frequent and less frequent for their self-reported levels of aim and effort for turning off the light during the Aospan task. Moreover, participants' Aospan-scores in the non-acting test phase were significant predictors of participants' Aospan-scores during the acting test phase, indicating that a higher score of working memory capacity on the first predicts a better performance on the latter. After accounting for the effects of non-acting working memory capacity scores, there was no significant difference between participants that non-acted frequent and less frequently for their acting working memory capacity scores.

Implications

The findings suggest that it was less difficult for participants to change their behaviour in a context of acting upon energy saving cues that were previously frequent non-acted upon, than when these cues were less frequently linked to non-acting. There was a significant difference between comparisons made of frequent non-acting participants and participants that non-acted less frequently for the manipulation check, indicating that participants had noticed the difference in presented cues during non-acting. However, the results did not support any of the hypotheses that were postulated. One possible explanation that could account for the absence of a difference between frequent and less frequent non-acting is that the non-acting cue was not strong enough to initiate an inhibitory behavioural response. Habitual behaviours arise through situational cues after frequent repetitions and sufficient pairings have made the response dependent of their cue (Orbell & Verplanken, 2010), which is stored as a learned cognitive structure in memory (Steg & Vlek, 2009). Therefore, the instruction to non-act upon the light bulb cue could be regarded as insufficient for triggering an inhibitory response that is learned and stored in memory. Hence, researchers need to be cautious as to calling patterns of non-acting behaviors habitual, as the concept of non-acting behavior entails the absence of a response, which makes it incompatible with the conceptualization of habits.

Subsequently, an undesired carry-over learning effect may explain why participants' Aospan-scores increased over. People generally experience difficulties with switching between dual-task configurations, but this interference can be reduced by practice (Ruthruff et al., 2006), as practice is a fundamental aspect of learning and improves performance through repetition (Toppino & Gerbier, 2014). This suggests that the non-acting test phase acted as a general repetition whereby participants grew accustomed to the processing-and-storage sequences of the Aospan task. This effect offers an explanation as to why the mean math and speed errors decreased over time, and the Aospan-scores and total number of correctly recalled letters increased during the acting test phase.

Furthermore, the discrimination process used to correctly discriminate between what information is relevant or irrelevant for the task at hand relies on a combination of cues and motivation and opportunity (Barrett et al., 2004). The self-reported levels of motivation, aim, and effort might also be an explanation for why participants that frequently non-acted omitted less energy saving behaviours than participants that non-acted less frequently. They indicate that participants who frequently non-acted were more motivated to turn off the light and it could therefore be a possibility that motivation weighed heavier on individuals' discrimination processed to determine what information was goal-relevant or irrelevant in comparison to the contextual cues. It could also be an addition as to why the non-acting cues were not strong enough to initiate an inhibitory behavioural response.

Limitations

There are some restrictions that undermine the implications following the results of the present study. The distribution of light bulb cues during the acting-test phase might have caused that the dual-task action setting was not challenging enough. The light bulb cues were ought to be evenly distributed during the acting test phase, so that participants were required to differentiate each time a letter was presented between light regulation and the Aospan-task. However, due to an error made when writing the adapted Aospan task script and data collection had already started, it was opted to continue with the same distribution as the high-frequent non-acting condition. It was expected that performing the Aospan task twice would cause participants to experience cognitive fatigue (Borragán et al., 2017), hampering performances in the dual-task action setting. However, some participants responded during debrief that turning off the light felt like it became an automatic response because the light bulb was disproportionately turned on. Therefore**,** distribution of light bulbs during the acting test phase is proposed as a limitation of the experiment.

A second limitation of the present design concerns the serial order of the Aospan task and the risk of carry-over learning effects. Generally, counterbalancing is a way of dealing with carry-over effects by varying the order of conditions between participants and experimental trials. As action omissions were uses as the dependent variable, it was not possible to divide the sample in half and have one of two groups complete the acting phase of the Aospan before completing the non-acting phase and have the other group complete it in reverse order. Participants would not be able to make action omissions when non-acting, because there would be no response possible to omit. A between subjects' design was therefore opted instead of a within subjects' design.

Finally, a third limitation of the experiment is related to the convenience sample used in the analysis and the lack of experiment control. After conducting a g*power analysis, a sample size of 81 participants was estimated as sufficient. However, only 73 out of 90 datasets were used for the analyses, which is a small sample for testing possible significant results. The accuracy criterion set by Unsworth et al. (2005) was adopted to ensure that participants focussed equally on the math and letter parts of the task. The other criteria were added because a zero value for the Aospan task during the non-acting test phase and a total amount of action omissions, were clear indications that participants did not understand all parts of the task correctly. In future research, larger sample sizes should be used or the subparts of the Aospan task should be explained more thoroughly so that less datasets should be excluded. In addition, it should be mentioned that the experiment was ought to be administered in a controlled lab environment. Unfortunately, due to the recent COVID-19 crisis, the experiment was redeveloped so that it could be administered online. Participants were encouraged before and throughout the task to solely focus on their performance and remain free of distractions. There was, however, no way to account for the influence of these confounders.

Future research

Because there are only a few researchers in the pro-environmental behaviours' literature studying the influence of habitual behaviours on household energy consumption, further investigations should focus on providing knowledge about how automated cognitive processes underly our day-to-day energy consumption. As mentioned previously, referring to non-acting behaviours as habits seems logically incompatible and it was therefore that no explicit or implicit measurement of habit was included in the experiment. It could, however, be interesting to use a broader conceptualization of habits to incorporate such an operationalization into the design and study how the self-reported frequency and consistency of past behaviour (Danner et al., 2008) or the self-report habit index (Verplanken & Orbell, 2003) influence pro-environmental behaviours. Moreover, the current frequency manipulation could be expanded by incorporating a habit formation procedure into the design. It would be expected that participants self-reported measurements of past behaviour and habits would have a negative impact on individual pro-environmental behaviours. Expectations regarding the current frequency manipulation would remain the same for when habit formation was incorporated.

Furthermore, there are three ways in which errors occur during routine sequential behaviours, namely perseveration errors, action omissions, and anticipation errors (Trafton et al., 2011). Perseveration errors occur when one repeats a previous action, while anticipation errors are skipped steps that are quickly rectified. The current design could also benefit from incorporating a within subjects' design to further explore the influence of frequent non-acting upon cues before acting. Participants' perseveration errors could be used as the dependent variable for the condition whereby participants had to act before non-acting, once they had already non-acted before acting. It would also be necessary to further adapt the Aospan task by alternating different letter and math parts between the conditions to account for effects of repetition. It would be expected that frequent non-acting before acting would lead to more errors than frequent acting before non-acting.

Conclusion

The aim of the study was to contribute to the pro-environmental behaviours literature by exploring whether it is more difficult to change behaviour in a context of frequent non-acting upon energy saving cues than when these contextual cues are less frequently linked to non-acting. The Aospan task served as a tool for measuring these effects, while simultaneously assessing individual working memory capacity. The findings suggest that there was no significant difference between frequent and less frequent non-acting for omitting actions after acting upon energy saving cues. In order to provide a better understanding of how rather automated cognitive processes underly frequent household energy consumption behaviours, future research is needed and addressed. Human unsustainable behaviour lies at the heart of contemporary environmental challenges, and as such, it is necessary to challenge common rationales, like the rational-actor paradigm in pro-environmental behaviours, to design effective behaviour change interventions.

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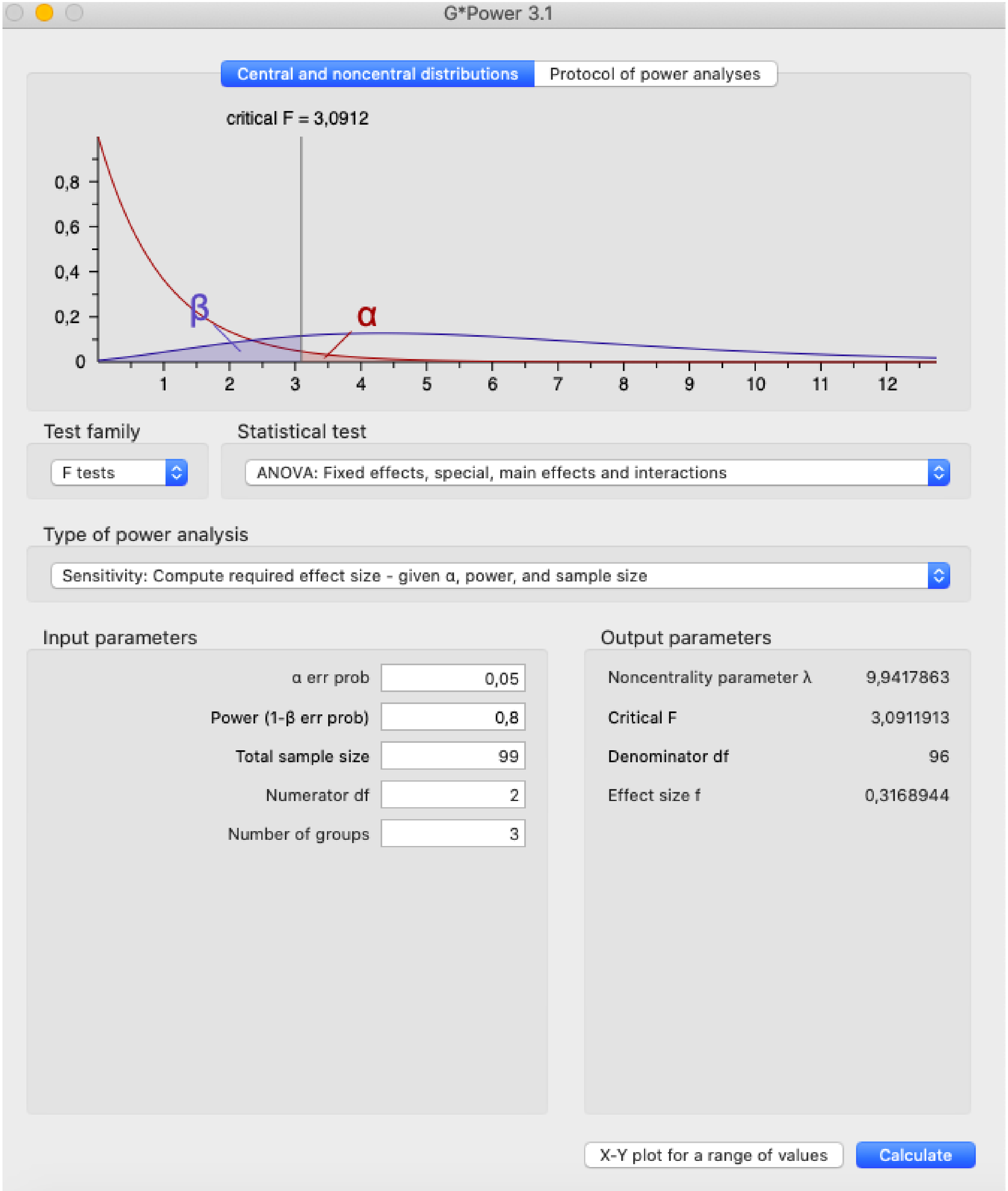
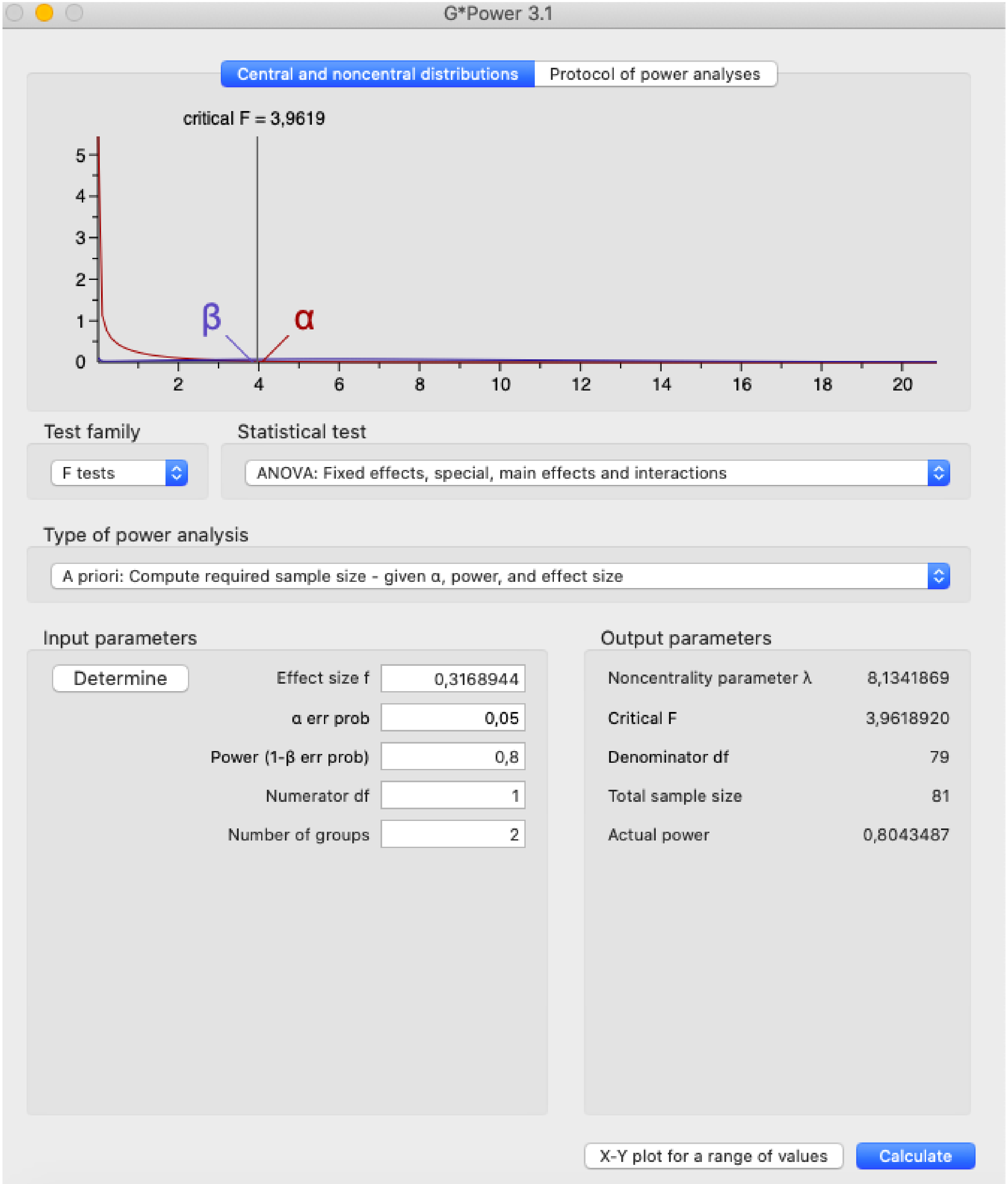
Appendix 1

G*power-analysis for the effect size of de Vries et al. (2011)



Appendix 2

G*power-analysis sample size present study



Appendix 3

Non-acting and acting cues