Journal of Economic Psychology 34 (2013) 88–96

Contents lists available at SciVerse ScienceDirect

Journal of Economic Psychology

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

Oops, I forgot the light on! The cognitive mechanisms supporting the execution of energy saving behaviors

Nicola Corradi [a], Konstantinos Priftis [a,b], Giulio Jacucci [c,d], Luciano Gamberini [a,*]

[a] Department of General Psychology, University of Padova Italy, Via Venezia 12, 35131 Padova, Italy
[b] Laboratory of Neuropsychology, IRCCS San Camillo Hospital, 70, Via Alberoni, 30126 Venice, Italy
[c] Helsinki Institute for Information Technology HIIT, Aalto University, PO Box 19800, 00076 Aalto, Finland
[d] Helsinki Institute for Information Technology HIIT, Department of Computer Science, University of Helsinki, PO Box 68, Gustaf Hällströmin katu 2b, 00014 Helsinki, Finland

ARTICLE INFO

Article history:
Received 20 March 2012
Received in revised form 22 October 2012
Accepted 17 November 2012
Available online 28 November 2012

JEL Classification:
Q50
Q30

PsycINFO Classification:
2340
2520
4070

Keywords:
Household energy conservation
Cognitive failure
Executive functions
Attention
Working memory
PASAT

ABSTRACT

Energy conservation and related environmental issues are of increasing interest for psychological research and intervention. In the present study, we investigated the cognitive abilities that are necessary in order for people to implement energy saving behaviors in their everyday life routines. We explored the relation between sustained attention, processing speed, and working memory and the participants' involvement in cognitively effortful energy saving behaviors. Results showed that the efficiency of the aforementioned cognitive mechanisms was positively related to the frequency of saving behaviors that required monitoring, integration, and inhibition to be implemented in daily behaviors and routines. The efficiency of the cognitive mechanisms that underlie our ability to implement energy saving actions might explain part of the gap between energy saving intention and energy wasting behavior. Ergonomic design of domestic appliances – reducing the cognitive demands of energy saving behaviors' – and compensatory training of the cognitive functions moderating the execution of energy saving behaviors can contribute to reduce energy consumptions.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Since the late 1970s, environmental paybacks of energy consumption have become one of the major concerns of the public opinion. Each year, human energy production results in the emission of roughly 30-thousand-billion tons of carbon dioxide (Energy Information Administration, 2008). Private household energy consumption produces an important quote of greenhouse gas emission. In the countries of the Organisation for Economic Co-operation and Development (OECD), for instance, households are typically responsible for roughly 15–20% of the total energy consumption (OECD, 2001). In addition, the residential share of CO^2 emissions is expected to keep rising (Biesiot & Noorman, 1999). Although more attention has

* Corresponding author. Tel.: +39 049 8276605; fax: +39 049 8276600.
E-mail address: luciano.gamberini@unipd.it (L. Gamberin.

0167-4870/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.joep.2012.11.002

been paid on improving technical efficiency (Berg, 1974), materials (Hawes, Feldman, & Banu, 1993), and exploitation of renewable sources (Sarkanen, 1976), today it appears clear that social and cognitive factors may play an important role in energy saving (Midden & Ritsema, 1983).

Psychological research has given an important contribution to energy conservation through interventions, which are based on the psychological mechanisms that lead people to saving or wasting behaviors (e.g., Abrahamse, Steg, Vlek, & Rothengatter, 2005; Becker, 1978; Biel & Thøgersen, 2007; McCalley & Midden, 2002; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007; Spagnolli et al., 2011; van Dam & van Trijp, 2011). Ajzen's (1991) theory of planned behavior has provided the theoretical framework used in the majority of studies that have investigated pro-environmental behaviors (e.g., Abrahamse & Steg, 2009; Bamberg & Moser, 2007; Bonnes & Bonaiuto, 2002; Heath & Gifford, 2002; Lynne, Casey, Hodges, & Rahmani, 1995; Taylor & Todd, 1995). The theory of planned behavior is an example of rational choice theory, which is based on the assumption that behavior is the result of a reasoned process of weighing costs and benefits of alternative actions (Ajzen, 1991). According to the theory of planned behavior, behavioral intentions (i.e., the intention to perform a behavior) are the most proximal predictors of behavior (Ajzen, 1991). In turn, behavioral intentions are determined by attitudes, perceived behavioral control, and subjective norms (Ajzen, 1991; Ajzen, Brown, & Carvajal, 2004; Grønhøj & Thøgersen, 2012).

While the theory of planned behavior suggests that behavioral intentions are the most proximal determinants of behavior, there is an important gap between intended and actual energy usage (e.g., Kantola, Syme, & Campbell, 1984). In a recent article, Steg (2008) has commented that "in many Western countries concern with environmental and energy problems is generally high. Yet, people often do not act in line with their concerns, and total household energy use is still rising". Several factors have been shown to moderate and mediate the gap between a resolution and its realization (for a definition of moderators and mediators, see Baron & Kenny, 1986): Economic factors (Steg, 2008), availability of products and services (Steg, 2008), habits (Loibl, Kraybill, & DeMay, 2011), personality traits (Conner, Grogan, Fry, Gough, & Higgins, 2009; Rhodes, Courneya, & Jones, 2003), perceived behavioral control (Richetin, Conner, & Perugini, 2011), temporal stability of intentions (Ajzen, 1996; Conner & Godin, 2007; Conner, Norman, & Bell, 2002; Conner, Sheeran, Norman, & Armitage, 2000), and implementation intentions (Gollwitzer, 1993, 1999; Gollwitzer & Sheeran, 2006) can affect the intention-behavior relation.

Recent studies have suggested that the realization of an intention can also be moderated by the efficiency of the cognitive processes underlying the intended behavior. For instance, the ability to inhibit a response moderates the association between behavioral intention and produced behavior, with reference to dietary and physical activities (Hall, Fong, Epp, & Elias, 2008). The discrepancy between healthy eating resolution and actual behavior (i.e., low intake of snacks/high intake of fruits and vegetables) is also moderated by switching/flexibility capabilities (Allan, Johnston, & Campbell, 2011). Furthermore, cognitive functions might moderate the realization of pro-environmental intentions. In fact, a number of energy saving behaviors can stress the cognitive processes that are necessary in order for us to execute them. Switching off the lights when leaving a room might imply the processing of both internal (e.g., "What is the estimated time away?") and external information (e.g., "Are there other people in the room?"), or the interruption of an ongoing action (e.g., leaving the room to answer the phone). Behaviors such as unplugging the battery charger when the mobile phone is loaded or turning off the heating before the food is fully cooked require the monitoring of an event (e.g., "Is the mobile charged now?") and the inhibition of possible distractors.

The implementation of these energy saving behaviors might be vulnerable to either the competition for cognitive resources (e.g., with other behaviors/mental actions) or their depletion (e.g., due to fatigue or limited resources). A failure of the required cognitive processes might hinder the execution of energy saving behaviors, leading to a waste of energy even in the presence of saving intentions. For instance, the failure to recall accurately which devices are currently in stand-by mode can prevent the users from turning off some of these devices. We will refer to energy saving behaviors that depend on supporting cognitive functions as Cognitive Effort Based Saving (CEBS). Nonetheless, it is often the case that (i) a saving behavior is intentionally withhold after a cost-benefit evaluation, or (ii) a saving behavior does not imply an additional cognitive effort. In these cases, saving behaviors are not constrained by the efficiency or the availability of the involved cognitive functions. For instance, when energy is intentionally wasted (e.g., turning-on the lights to prevent stealing in case we are out of home) energy saving is opposed by a conscious decision and not by a limited efficiency/availability of underlying cognitive processes. Other energy saving behaviors do not increase the cognitive workload: These energy saving behaviors (e.g., preferring a low-temperature setting for the washing machine) do not require additional cognitive steps with respect to the associated wasting behavior (i.e., using a high-temperature setting), thus, should not depend on the availability of cognitive resources. For instance, carrying out the decision to purchase an energy-efficient washing machine is hardly moderated by the efficiency of our cognitive processes. Under these circumstances, it is unlikely that a cognitive lapse turns an energy saving decision into a wasting behavior: A cognitive error can compromise the behavior (e.g., forgetting to go to buy the washing machine), but is unlikely that will turn it into an energy wasting action (e.g., purchasing a high-consumption appliance by mistake). We referred to the energy saving behaviors that do not stress the underlying cognitive processes as Choice Based Saving (CBS). The schematic comparison between the two types of saving behavior is depicted in Fig. 1.

We hypothesized that sustained attention, speed of processing, and working memory support the execution of CEBS behaviors. Attention is the mechanism by which high-level mental states select and exert causal control over more automatic cognitive processes (Posner & Petersen, 1990). Sustained attention – or endogenous modulation of alertness – is defined as "the ability to self-sustain mindful, conscious processing of stimuli whose repetitive, non-arousing qualities would otherwise lead to habituation and distraction to other stimuli" (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). In

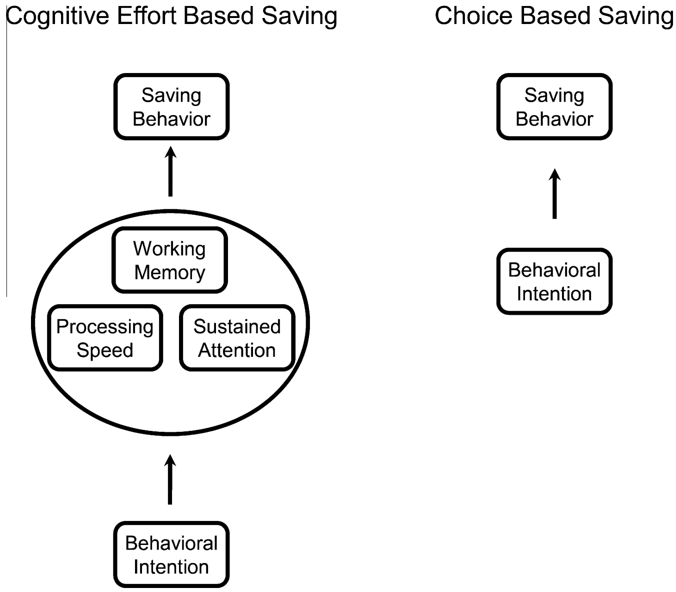

Fig. 1. Schematic description of models of CEBS and CBS behaviors.

studies on healthy participants and brain-damaged patients, Robertson et al. (1997) showed that sustained attention is strongly related to everyday cognitive lapses: A transitory reduction of the attentional resources allocated to a saving behavior might produce a cognitive lapse, thus, twisting the saving behavior into a wasting action. For instance, turning off the electric stove in advance to exploit its residual heat requires the continuous and voluntary monitoring of the cooking process by means of sustained attention. Speed of processing refers to the speed at which information is processed during mental operations (Salthouse, 1996). Action/performance monitoring is related to the processing speed of environmental input: High processing speed is inversely correlated with the number of undetected errors in skilled cognitive tasks (Bell & Gardner, 1997). Speed of processing can contribute to the detection – and correction – of errors in the execution of CEBS behaviors. Moreover, fast processing of environmental input reduces the users' cognitive workload (Wu & Liu, 2007), and can facilitate the execution of CEBS behaviors under time constraints. Working memory is the system responsible for the temporary storage and manipulation of the information necessary to guide behavior (Baddeley, 1986). Theoretical (Baddeley, 1986), functional neuroimaging (Bunge, Klingberg, Jacobsen, & Gabrieli, 2000), and behavioral (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010) studies have suggested that working memory shares a common cognitive and neural substrate with that of the executive functions (i.e., functions controlling the low-level cognitive processes and goal-directed behavior). For instance, McCabe et al. (2010) have showed that measures of executive functions are highly correlated with working memory capacity ($r = 0.97$), and with speed of processing ($r = 0.79$). Two subsystems of working memory can play a key role in the execution of CEBS behaviors. The central executive is the component of working memory that acts as the "supervisor or scheduler, capable of selecting strategies and integrating information from various sources" (Baddeley, 1986). Baddeley equated the central executive subsystem to Norman and Shallice (1986) Supervisory Attentional System (SAS). The central executive subsystem-SAS is responsible for the activation of a specific thought or behavioral schema by allocating attention to it. Detailed studies on the central executive have showed that it involves the ability to focus attention on a task, to divide attention among tasks, and to switch among tasks, the latter being related to the phonological loop as well (for a review, see Baddeley, 2002). The phonological loop is the subsystem of working memory that controls the short-term retention of phonological-verbal information (Baddeley, 1986). The phonological loop is activated when a CEBS behavior requires the processing of phonological-verbal information, which must be gathered – from the environment or from long-term memory – and maintained online for the time necessary to complete the task at hand. The storage and manipulation of information, the switching between different task sequences, and the inhibition of irrelevant behaviors/information can be essential to a wide range of CEBS behaviors. For instance, the final action to unplug the battery-charger when the battery is loaded can require the user to temporary store information about the devices in charge, to switch periodically to check the battery's state, and, finally to inhibit ongoing actions in order to unplug the device.

One of the most widely-used tests in the study of higher cognitive functions is the Paced Auditory Serial Addition Test (PASAT; Gronwall, 1977; Stablum, Umiltà, Mazzoldi, Pastore, & Magon, 2007). Indeed, the PASAT is very sensitive in evaluating sustained attention, processing speed, and working memory (for a review, see Tombaugh, 2006). In fact, performance on the PASAT seems to be sensitive to the cognitive mechanisms underlying the everyday execution of routines and complex behaviors: Performance in the PASAT is correlated with everyday cognitive failures and with the ability to carry out everyday life routines (Bate, Mathias, & Crawford, 2001; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996; Robertson et al., 1997).

The aim of the present study was to investigate the relation between CEBS and CBS behaviors, on the one hand, and cognitive mechanisms supporting their execution (i.e., working memory, speed of processing, and sustained attention), on the other hand. To this aim, we investigated the relations between the PASAT and measures of CEBS and CBS. We hypothesized that the extent of participants' involvement in CEBS behaviors would be related to the efficiency of their underlying cognitive processes (sustained attention speed of processing, and working memory capacity), whereas CBS behaviors would not be related to the cognitive processes that we have explored in the present study.

2. Method

2.1. Participants

The study was approved by the Ethics Committee of the University of Padova, and all participants provided written informed consent after the procedure had been fully explained to them, according to the Declaration of Helsinki. Fifty participants were recruited in non-academic public libraries. The researchers contacted library users and asked them to participate to a brief study on energy conservation. Given that the execution of the PASAT might generate negative mood (Lezak, 1995), we paid special attention to inform the participants of their right to withdraw their participation from the study at any moment. Ten participants withdrew their consent during the administration of the PASAT. At the end of the experimental session, each participant was interviewed in order for us to assess the presence of events that interfered with task performance (e.g., people talking loudly, children interrupting the session, etc.). Three participants reported external events that interfered with task execution and, thus, they were excluded from the study. Thirty-seven participants completed the study (mean age = 41 years, *SD* = 8.2; mean education = 15.76 years, *SD* = 3.77; 22 females).

2.2. Materials and procedure

Participants were asked to respond to a questionnaire on energy saving and to carry out a computerized version of the PASAT (adapted from Stablum et al., 2007). Task order was counterbalanced across participants. In the PASAT, a series of 60 spoken number words (speed = 1 word/2.2 s) was presented through headphones to each participant. Participants were asked to add each digit to the digit immediately preceding it and to give the answer orally. Accuracy (i.e., correct response/total items; errors and omissions were considered as incorrect responses) was calculated for each participant. The questionnaire began with two questions exploring participant's involvement in energy conservation. We explained to the participants that energy conservation is the commitment to reduce the personal energy consumption in daily life through specific actions and practices. In the first question we asked participants to rate their involvement in energy saving on a four point scale (i.e., very involved, involved, uninvolved, very uninvolved). In the second question we asked the participants whether they were responsible for the payment of their energy consumption or whether that payment was included in other payments (e.g., rent) as a flat rate. The main section of the questionnaire was composed by 18 three-choice items exploring the frequency of daily energy-related behaviors (i.e., always, sometimes, never). Although five and seven-point scales are more common, we have preferred to use a three-point scale. Fewer response points can reduce the sensitivity to bias because of between-respondents differences in response style (Clarke, 2001; Cronbach, 1946, 1950). In addition, the gains in validity and reliability with the increase in the response points is debated (Felix, 2011; Jacoby & Matell, 1971; Matell & Jacoby, 1971; Maxell & Jacoby, 1972; but for a review of studies recommending longer scales, see Cox, 1980). We measured the frequencies of CBS and CEBS behaviors through two sets of, respectively, 12 and 6 items. CBS and CEBS were measured by calculating the mean for the items in each set, assigning the value 1 to the lowest frequency (i.e., never), the value 2 to medium frequency (i.e., sometimes), and the value 3 to the highest frequency (i.e., always; Bass, Cascio, & O' Connor, 1974). In the case of reversely-coded items (i.e., items relative to the frequencies of wasting behaviors) we assigned the value 3 to the lowest frequency and 1 to the highest frequency. In brief, high scores indicate high frequencies of saving behaviors.

The two sets of items (i.e., those used for CBS and CEBS measures) were defined a priori during the construction of the questionnaire. Items used in the CBS measure (i) were referred to a tradeoff decision resulting in a deliberate waste of energy or (ii) explored energy saving behaviors that require minimal or no cognitive load, and (iii) could not be turned into a wasting behavior by a cognitive slip. Items used in the CEBS measure (i) did not include a cost-benefits justification for the waste of energy, (ii) explored energy saving behaviors that require a relevant cognitive load, (iii) and which can be turned into energy wasting behaviors by a cognitive slip. The CBS measure included 12 three-choice items such as "When I buy a new electric appliance, I pay attention to the energy class" and "I leave lights or televisions turned on when nobody is at home, in order to discourage thieves". The CEBS measure included 6 three-choice items such as "When I cook, I turn-off the heating before the food is fully cooked in order to exploit the residual warmth".

3. Results

The estimated lower bounds of the reliability (i.e., Cronbach's alpha) for the CBS and the CEBS measures were low (i.e., 0.38 and 0.31 respectively). This finding is not surprising, given that these measures are composed by few items (Cortina, 1993) and there is a large variability across energy saving behaviors. In fact, the variability in the commitment to different energy saving behaviors is greater than the variability between individuals' commitment to save energy (Spagnolli, Jacucci, Gamberini, Corradi, & Zamboni, submitted for publication). We were able to improve the reliability to a good-enough level (i.e., ≈0.50; Schmitt, 1995) by removing the two weakest items from each measure increasing Cronbach's alpha for the CEBS and the CBS measures to .46 and 0.48, respectively. Nonetheless, given that low reliability does not increase the probability of type I errors (Zuckerman, Hodgins, Zuckerman, & Rosenthal, 1993) and that the results of the analysis remained stable, when the weak items were included or omitted, we decided to report the analysis conducted with the initial sets of items.

All participants declared to be interested about environmental issues: 75% of the participants reported to be "very involved" in energy conservation, while the remaining 25% stated to be "involved" in energy conservation. In fact, the reported frequencies of CEBS and CBS behaviors were quite high: the mean score was 2.48 ($SD = 0.25$) for the CEBS measure and 2.64 ($SD = 0.24$) for the CBS measure. The mean accuracy on the PASAT was .80% ($SD = 0.15$).To explore the relations between effort-based saving and the efficiency of the supporting cognitive processes, we computed a hierarchical multiple regression model between the score in the CEBS measure and the accuracy on the PASAT (see Fig. 2, panel A).

On the first step, we entered the control variables of age and education, both measured in years. On the second step, we entered the accuracy on the PASAT. Sustained attention, processing speed, and working memory capacity, measured through participants' accuracy on the PASAT, were significantly related to the score in the CEBS measure, $\beta = 0.371$, $t(33) = 2.33$, $p = .02$, whereas Education, $\beta = -0.197$, $t(33) = -1.15$, $p = 0.26$, and Age, $\beta = 0.002$, $t(33) = 0.01$, $p = .99$, were not. Then, we calculated Cook's distance for each of our data points to identify potential outliers that could have influenced the results (i.e., Cook's distance >1; Cook & Weisberg, 1982; Stevens, 2009). We did not detect any points that had a significant influence on the regression coefficients. Accelerated bias-corrected confidence intervals for regression coefficients, obtained through 1000 bootstrap resampling, substantially confirmed the results of the regression analysis (see Table 1).

After having controlled for the effects of Age and Education, performance on the PASAT accounted for the 14% of the total variance in the CEBS measure. With the CBS measure as the criterion variable (see Fig. 2, panel B), the same regression analysis did not reveal significant effects of Education, $\beta = -0.152$, $t(33) = -0.83$, $p = 0.41$, of Age ($\beta = 0.145$, $t(33) = 0.79$, $p = 0.44$), or of the accuracy on the PASAT ($\beta = -0.017$, $t(33) = -0.01$, $p = 0.92$). Accelerated bias-corrected confidence intervals for regression coefficients, obtained through 1000 bootstrap resampling, substantially confirmed the results of the regression analysis (see Table 2).

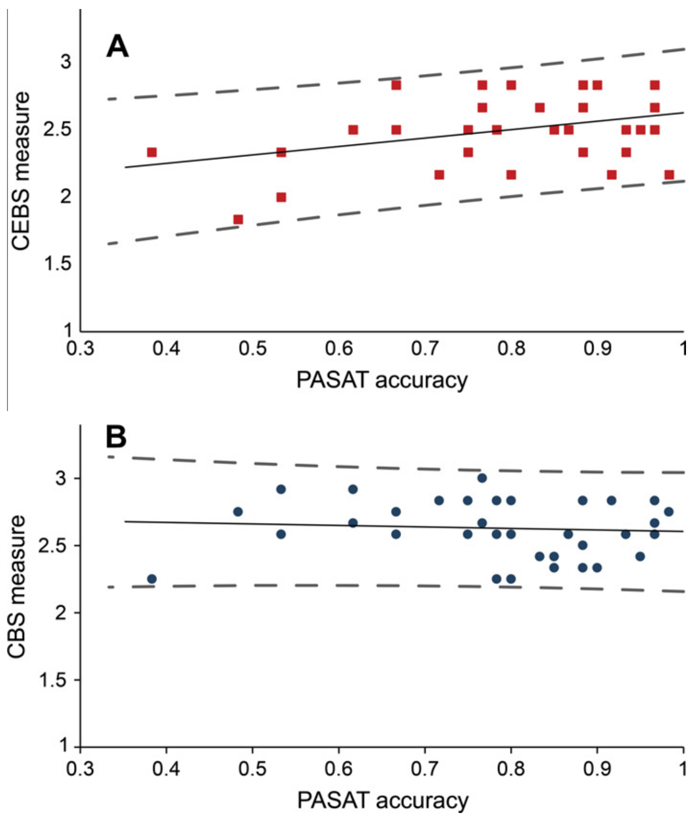

Fig. 2. Scatter plot of the relation between the performance on the PASAT and the involvement in energy saving. The relation between accuracy on the PASAT and the CEBS measure is shown in panel A, whereas the relation between accuracy on the PASAT and the CBS measure is shown in panel B. Dashed lines represents the limits of 95% prediction interval.

Table 1
Multiple regression on CEBS measure.

	β	t(33)	p	BCa confidence intervals	
				Lower	Upper
Education	−0.197	−1.153	.257	−0.4580	0.3377
Age	0.002	0.014	.989	−0.3034	0.3843
PASAT	0.371	2.332	.026	0.0922	0.7346

Note: $N = 37$, β represents the standardized regression coefficient.

Table 2
Multiple regression on CBS measure.

	β	t(33)	p	BCa confidence intervals	
				Lower	Upper
Education	−0.152	−0.830	.412	−0.3898	0.4996
Age	0.145	0.787	.437	−0.2376	0.5133
PASA/T	−0.017	−0.098	.922	−0.4229	0.3172

Note: $N = 37$, β represents the standardized regression coefficient.

4. Discussion

The results of the present study suggest that sustained attention, processing speed, and working memory can be related to and, thus, predict the occurrence of CEBS behaviors. The accuracy on the PASAT explained a consistent quote of unique variance in the CEBS ($R^2 = .14$). That is, energy saving behaviors that imply the monitoring and planning of scheduled actions (e.g., turn-off the lights when leaving a room for a long time) seem to rely on sustained attention, processing speed, and working memory mechanisms. In contrast, when energy saving behaviors are determined by a simple decision to take (e.g., which device to buy) or the behavior is so simple to be carried out with no special monitoring of actions, then sustained attention, processing speed, and working memory mechanisms are less involved. In the present study we investigated, for the first time, the role of participants' higher cognitive functions in implementing saving behaviors in everyday life routines. The inclusion of this "implementation ability" – in this case represented by sustained attention, processing speed, and working memory capacity – might help explaining the frequently observed gap between positive attitudes towards energy saving and actual energy consumption (e.g., Kantola et al., 1984). Nonetheless, without affecting the overall validity of the study (i.e., the probability of a type I error; Zuckerman et al., 1993), our small sample can limit the precision of our effect sizes estimates (Anderson & Vingrys, 2001). In fact, the confidence intervals for the proportion of variance in the CEBS and the CBS measure, explained by participants' accuracy on the PASAT (R^2) are relatively large (i.e., 0.006–0.383 and 0.000–0.002 respectively, calculated through 1000 bootstrap resampling, using the accelerated bias-corrected method). Further studies with greater power are needed for a more precise estimate of the strength of the relations between CEBS behaviors and sustained attention, processing speed, and working memory. One may wonder about the ecological validity of our measure of CEBS behaviors, given that we relied on self-report and we did not measure participants' behavioral intentions or observe their behaviors in everyday life: Observation and measuring of behavior should be the focus of future studies. Nonetheless, a recent study has showed that cognitive load decreases the odds of observing a saving behavior (Corradi, Priftis, Jacucci, & Gamberini, submitted for publication). Further studies are required in order to explore the specific contribution of each cognitive mechanism, and their interaction with intentions, norms, attitudes, and perceived behavioral control, while moderating energy saving efforts.

The waste of energy resulting from a cognitive failure might be reduced by specific psychological interventions, focused either on the energy saving behaviors or on the users' cognitive processes. Suitable design of appliances and devices can decrease the cognitive load required for performing energy saving behaviors, thus, supporting their stable inclusion in daily routines. For instance, we could design devices that make more evident to the user both the waste of energy and the improper use of the device (e.g., alerting the user if a devices remains in standby mode for a prolonged time; Spagnolli et al., 2011). Devices could be designed to include features that prompt implementation intentions or to provide situational cues that trigger existing implementation intentions; these cues can decrease the dependence of a behavior on the underlying cognitive processes (Parks-Stamm, Gollwitzer, & Oettingen, 2007; for the use of appliance-based technologies to generate situation-dependent advices, see Spagnolli et al., 2011).

Implementation intentions are "if-then" plans that associate an anticipated situation to a predetermined response (Gollwitzer, 1993, 1999; Gollwitzer & Sheeran, 2006). Following this association, the control of goal-directed behavior is no longer based exclusively on the behavioral/goal intention (i.e., people's commitment to the goal) but it is also sustained by the (expected) situational stimuli: When people formulate an implementation intention the "gap" between intention and behavior is dramatically reduced (Gollwitzer, 1999; Gollwitzer & Sheeran, 2006). After an implementation intention is established the critical situation will trigger the goal-directed behavior in a fashion similar to that of the exogenous trigger of habitual behavior (Gollwitzer, 1999). Implementation intentions allow to avoid the conscious, effortful control of action: When the situation occurs, the intended action is executed automatically, bypassing conscious decision. In this way, people can turn to automatic behavior control, instead of relying on the conscious trigger of action (Ajzen, Czasch, & Flood, 2009). In fact, implementation intentions improve initiation of goal-directed behaviors even in patients affected by neurological disorders, such as patients with frontal lobe damage and opiate addicts under withdrawal (Brändstatter, Lengfelder, & Gollwitzer, 2001; Lengfelder & Gollwitzer, 2001).

Another approach could be that of training the involved cognitive functions to improve users' saving capabilities. Cognitive training can improve sustained attention, speed of processing, and working memory, and this improvement could be generalized to our activities in everyday life (Ball, Edwards, & Ross, 2007; Robertson & Garavan, 2004; Robertson, Tegnér, Tham, Lo, & Nimmo-Smith, 1995; Westerberg et al., 2007). Thus, some people involved in energy saving might benefit from a compensatory training of cognitive functions supporting the execution of energy saving behaviors, especially when the implementation of the desired behaviors during everyday life routines becomes difficult.

Overall, our results suggest that our understanding of energy conservation behaviors might be improved by considering the influence of cognitive mechanisms underlying the execution of energy saving behaviors. A failure in the underlying cognitive processes can hinder the intended saving behavior, thus leading to a waste of energy. Considering the cognitive mechanisms underlying the execution of pro-environmental behaviors might not just improve our understanding of the leap between saving intention and wasting behavior, but also through a more effective psychological intervention this can lead to major financial and environmental benefits.

Acknowledgements

The authors are deeply indebted to Prof. Franca Stablum, Prof. Andrea Facoetti, Dr. Giovanna Mioni, Dr. Francesco Martino, and Dr. Giorgio Arcara for their support and collaboration. This work has been co-funded by the European Union through the BeAware STREP Project (EU FP7/ICT-2007.6.3, Project No. 224557, http://energyawareness.eu). We thank all the partners in the BeAware consortium and all the participants for their time and effort.

References

Abrahamse, W., & Steg, L. (2009). How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? *Journal of Economic Psychology, 30*, 711–720.

Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology, 25*, 273–291.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179–211.

Ajzen, I., Brown, T. C., & Carvajal, F. (2004). Explaining the discrepancy between intentions and actions: The case of hypothetical bias in contingent valuation. *Personality and Social Psychology Bulletin, 30*, 1108–1121.

Ajzen, I., Czasch, C., & Flood, M. G. (2009). From intentions to behavior: Implementation intention, commitment, and conscientiousness. *Journal of Applied Social Psychology, 39*, 1356–1372.

Ajzen, I. (1996). The directive influence of attitudes on behavior. In P. M. Gollwitzer & J. A. Bargh (Eds.), *The psychology of action: Linking cognition and motivation to behavior* (pp. 385–403). New York: Guilford Press.

Allan, J. L., Johnston, M., & Campbell, N. (2011). Missed by an inch or a mile? Predicting the size of intention-behaviour gap from measures of executive control. *Psychology & Health, 26*, 635–650.

Anderson, A. J., & Vingrys, A. J. (2001). Small samples: Does size matter? *Investigative Ophthalmology & Visual Science, 42*, 1411–1413.

Baddeley, A. (1986). *Working memory*. Oxford: Oxford University Press.

Baddeley, A. (2002). Is working memory still working? *European Psychologist, 7*, 85–97.

Ball, K., Edwards, J. D., & Ross, L. A. (2007). The impact of speed of processing training on cognitive and everyday functions. *The Journals of Gerontology Series B, 62*, 19–31.

Bamberg, S., & Moser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology, 27*, 14–25.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173–1182.

Bass, B. M., Cascio, W. F., & O' Connor, E. J. (1974). Magnitude estimations of expressions of frequency and amount. *Journal of Applied Psychology, 59*, 313–320.

Bate, A. J., Mathias, J. L., & Crawford, J. R. (2001). Performance on the test of everyday attention and standard tests of attention following severe traumatic brain injury. *The Clinical Neuropsychologist, 15*, 405–422.

Becker, L. J. (1978). Joint effect of feedback and goal setting on performance. A field study of residential energy conservation. *Journal of Applied Psychology, 63*, 428–433.

Bell, B., & Gardner, M. (1997). Individual differences in undetected errors in skilled cognitive performance. *Learning and Individual Differences, 9*, 43–61.

Berg, C. A. (1974). Technical basis for energy conservation. *Mechanical Engineering, 96*, 30–42.

Biel, A., & Thøgersen, J. (2007). Activation of social norms in social dilemmas: A review of the evidence and reflections on the implications for environmental behavior. *Journal of Economic Psychology, 28*, 93–112.

Biesiot, W., & Noorman, K. J. (1999). Energy requirements of household consumption: A case study of the Netherlands. *Ecological Economics, 28*, 367–383.

Bonnes, M., & Bonaiuto, M. (2002). Environmental psychology: From spatial-physical environment to sustainable development. In R. Bechtel & A. Churchman (Eds.), *Handbook of environmental psychology* (pp. 28–54). New York: Wiley.

Brändstatter, V., Lengfelder, A., & Gollwitzer, P. M. (2001). Implementation intentions and efficient action initiation. *Journal of Personality and Social Psychology, 81*, 946–960.

Bunge, S. A., Klingberg, T., Jacobsen, R. B., & Gabrieli, J. D. E. (2000). A resource model of the neural basis of executive working memory. *Proceedings of the National Academy of Sciences, 97*, 3573–3578.

Clarke, I. III, (2001). Extreme response style in cross-cultural research. *International Marketing Review, 18*, 301–324.

Conner, M., & Godin, G. (2007). Temporal stability of intentions as a moderator of intention-health behaviour relationships. *Psychology & Health, 22*, 875–896.

Conner, M., Grogan, S., Fry, G., Gough, B., & Higgins, A. R. (2009). Direct, mediated and moderated impacts of personality variables on smoking initiation in adolescents. *Psychology & health, 24*, 1085–1104.
Conner, M., Norman, P., & Bell, R. (2002). The theory of planned behavior and healthy eating. *Health Psychology, 12*, 194–201.
Conner, M., Sheeran, P., Norman, P., & Armitage, C. J. (2000). Temporal stability as a moderator of relationships in the theory of planned behaviour. *British Journal of Social Psychology, 39*, 469–493.
Cook, D. R., & Weisberg, S. (1982). *Residuals and influence in regression*. New York: Chapman and Hall.
Corradi, N., Priftis, K., Jacucci, G., & Gamberini, L. (submitted for publication). *The role of central executive in energy saving behaviors.*
Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78*, 98–104.
Cox, E. P. III, (1980). The optimal number of response alternatives for a scale: A review. *Journal of Marketing Research, 17*, 407–422.
Cronbach, L. J. (1946). Response sets and test validity. *Educational and Psychological Measurement, 6*, 475–494.
Cronbach, L. J. (1950). Further evidence on response sets and test design. *Educational and Psychological Measurement, 10*, 3–31.
Energy Information Administration (2008). *International Energy Statistics.* <http://www.tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8>.
Felix, R. (2011). The impact of scale width on responses for multi-item, self-report measures. *Journal of Targeting, Measurement and Analysis for Marketing, 19*, 153–164.
Gollwitzer, P. M. (1993). Goal achievement: The role of intentions. *European Review of Social Psychology, 4*, 141–185.
Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist, 54*, 493–503.
Gollwitzer, P. M., & Sheeran, P. (2006). Implementation intentions and goal achievement: A meta-analysis of effects and processes. *Advances in Experimental Social Psychology, 38*, 69–119.
Grønhøj, A., & Thøgersen, J. (2012). Action speaks louder than words: The effect of personal attitudes and family norms on adolescents' pro-environmental behaviour. *Journal of Economic Psychology, 33*, 292–302.
Gronwall, D. M. (1977). Paced auditory serial-addition task: A measure of recovery from concussion. *Perceptual and Motor Skills, 44*, 367–373.
Hall, P. A., Fong, G. T., Epp, L. J., & Elias, L. J. (2008). Executive function moderates the intention-behavior link for physical activity and dietary behavior. *Psychology & Health, 23*, 309–326.
Hawes, D. W., Feldman, D., & Banu, D. (1993). Latent heat storage in building materials. *Energy and Buildings, 20*, 77–86.
Heath, Y., & Gifford, R. (2002). Extending the theory of planned behavior: Predicting the use of public transportation. *Journal of Applied Social Psychology, 32*, 2154–2189.
Jacoby, J., & Matell, M. S. (1971). Three-point Likert scales are good enough. *Journal of Marketing Research, 8*, 495–500.
Kantola, S. J., Syme, G. J., & Campbell, N. A. (1984). Cognitive dissonance and energy conservation. *Journal of Applied Psychology, 69*, 416–421.
Lengfelder, A., & Gollwitzer, P. M. (2001). Reflective and reflexive action control in patients with frontal brain lesions. *Neuropsychology, 15*, 80–100.
Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.
Loibl, C., Kraybill, D. S., & DeMay, S. W. (2011). Accounting for the role of habit in regular saving. *Journal of Economic Psychology, 32*, 581–592.
Lynne, G. D., Casey, C. F., Hodges, A., & Rahmani, M. (1995). Conservation technology adoption decisions and the theory of planned behavior. *Journal of Economic Psychology, 16*, 581–598.
Matell, M. S., & Jacoby, J. (1971). Is there an optimal number of alternatives for Likert scale items? I. Reliability and validity. *Educational and Psychological Measurement, 31*, 657–674.
Maxell, M. S., & Jacoby, J. (1972). Is there an optimal number of alternatives for Likert-scale items? Effects of testing time and scale properties. *Journal of Applied Psychology, 56*, 506–509.
McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: Evidence for a common executive attention construct. *Neuropsychology, 24*, 222–243.
McCalley, L. T., & Midden, C. J. H. (2002). Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation. *Journal of Economic Psychology, 23*, 589–603.
Midden, C. J. H., & Ritsema, B. S. M. (1983). The meaning of normative processes for energy conservation. *Journal of Economic Psychology, 1–2*, 37–55.
Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and Self-regulation* (pp. 1–18). New York: Plenum Press.
OECD (2001). *Environmental outlook*. Paris: Organisation for Economic Co-operation and Development.
Parks-Stamm, E. J., Gollwitzer, P. M., & Oettingen, G. (2007). Action control by implementation intentions: Effective cue detection and efficient response initiation. *Social Cognition, 25*, 248–266.
Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13*, 25–42.
Rhodes, R. E., Courneya, K. S., & Jones, L. W. (2003). Translating exercise intentions into behavior: Personality and social cognitive correlates. *Journal of Health Psychology, 8*, 447–458.
Richetin, J., Conner, M., & Perugini, M. (2011). Not doing is not the opposite of doing: Implications for attitudinal models of behavioral prediction. *Personality and Social Psychology Bulletin, 37*, 40–54.
Robertson, I. H., & Garavan, H. (2004). Vigilant attention. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (3rd ed., pp. 631–640). Cambridge: MIT Press.
Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). "Oops!": Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia, 35*, 747–758.
Robertson, I. H., Tegnér, R., Tham, K., Lo, A., & Nimmo-Smith, I. (1995). Sustained attention training for unilateral neglect: Theoretical and rehabilitation implications. *Journal of Clinical and Experimental Neuropsychology, 17*, 416–430.
Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1996). The structure of normal human attention: The Test of Everyday Attention. *Journal of the International Neuropsychological Society, 2*, 525–534.
Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103*, 403–428.
Sarkanen, K. V. (1976). Renewable resources for the production of fuels and chemicals. *Science, 191*, 773–776.
Schmitt, N. (1995). Uses and abuses of coefficient alpha. *Psychological Assessment, 8*, 350–353.
Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science, 18*, 429–434.
Spagnolli, A., Corradi, N., Gamberini, L., Hoggan, E., Jacucci, G., Katzeff & Jonsson, L. (2011). Eco-feedback on the go: Motivating energy awareness. *Computer, 44*, 38–45.
Spagnolli, A., Jacucci, G., Gamberini, L., Corradi, N., & Zamboni, L. (submitted for publication). *Understanding waste: Lessons learned while designing an eco-feedback application.*
Stablum, F., Umiltà, C., Mazzoldi, M., Pastore, N., & Magon, S. (2007). Rehabilitation of endogenous task shift processes in closed head injury patients. *Neuropsychological Rehabilitation, 17*, 1–33.
Steg, L. (2008). Promoting household energy conservation. *Energy Policy, 36*, 4449–4453.
Stevens, J. (2009). *Applied multivariate statistics for the social sciences* (5th ed.). New York: Routledge.
Taylor, S., & Todd, P. (1995). An integrated model of waste management behavior: A test of household recycling and composting intentions. *Environment and Behavior, 27*(5), 603–630.
Tombaugh, T. N. (2006). A comprehensive review of the Paced Auditory Serial Addition Test (PASAT). *Archives of Clinical Neuropsychology, 21*(1), 53–76.
van Dam, Y. K., & van Trijp, H. C. M. (2011). Cognitive and motivational structure of sustainability. *Journal of Economic Psychology, 32*, 726–741.
Westerberg, H., Jacobaeus, H., Hirvikoski, T., Clevberger, P., Ostensson, M. L., Bartfai, A., et al. (2007). Computerized working memory training after stroke-A pilot study. *Brain Injury, 21*(1), 21–29.

Wu, C., & Liu, Y. (2007). Queuing network modeling of driver workload and performance. *IEEE Transactions on Intelligent Transportation Systems, 8*(3), 528–537.

Zuckerman, M., Hodgins, H. S., Zuckerman, A., & Rosenthal, R. (1993). Contemporary issues in the analysis of data: A survey of 551 psychologists. *Psychological Science, 4*, 49–53.