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COGNITIVE MODELS OF ENERGY SAVING

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Abstract - English

A number of studies have explored the role of psychological factors in the production of energy saving and pro-environmental behaviors. The theory of planned behavior, the norm activation model, and the new environmental paradigm provided the theoretical model to the majority of the studies in the field. Other isolated psychological factors that were connected with the production of pro-environmental behavior were the exposition to social norms, pre-existing environmental values and motivations, the emotional involvement, the locus of control, and environmental knowledge and awareness.

Yet, some pro-environmental decisions are converted in actual behaviors, while others are not. In fact some pro-environmental behaviors require an adequate infrastructure. As well, the influence of personal norms depends on situational cues. The gap between intention and behavior is mediated by the temporal stability of the intentions, the perceived behavioral control, and the formation of implementation intentions.

Two recent studies have shown how executive functions mediate the decision-behavior gap for physical activity and dietary behaviors. We hypothesized that when the saving behaviors stress the underlying cognitive processes then the cognitive efficiency (especially the efficiency of the functions involved in action control) mediates the production of energy saving behaviors. To test this hypothesis we conducted three experiments. In the first we examined the relation between of working memory, speed of processing, and sustained attention with the self-reported production of energy saving behavior. Results suggested that the

efficiency of the aforementioned functions predicts the production of energy saving behaviors that imply a cognitive effort to be implemented in daily routines. In the second experiment we examined the role of working memory, speed of processing and sustained attention on the production of a directly observed saving behavior, turning off the light when leaving the laboratory. In this case, the relationship was not significant, possibly because some participants refrain form the production of the saving behavior because they did not felt authorized to interact with the laboratory equipment. In the third experiment we "authorized" the participants to handle the laboratory's devices asking to turn them on at the beginning of the experimental session. Then, trough a dual task paradigm we examined the role of central executive load on the production of energy saving behaviors. Result showed that the central executive load (i.e., through random number generation) decreases the production of the saving behaviors that are not connected with an evident environmental cue.

Feedback is commonly used in psychological studies aimed to reduce energy consumption. Feedback acts as a self-teaching tool that allows users to learn from their experience and the consequences of their behaviors. Previous studies showed that feedback resulted to be more effective when is immediate, conveys few information, and is supported by a goal. In the BeAware project we developed an application (i.e., EnergyLife) aimed to reduce energy consumption through an mobile-based feedback. EnergyLife included a community level to provide a climax of cooperative competition and a social goal, to maximize the effect of the feedback. The feedback provided by EnergyLife was next to-real time. Moreover, persuasive advice tips (generic and smart/context-aware) were provided to the users. The effectiveness of EnergyLife was evaluated in a trial involving 5 households and 14 users. The analysis on energy consumption trend showed a significant decrease in energy consumption for all the families in the trial. Overall, the household show a significantly progressive reduction of the consumptions respect to the previous year. Moreover, when a user read a smart advice the consumption of the specific appliance decreased.

Overall, results suggest that our understanding of energy conservation behaviors might be improved by considering the influence of cognitive mechanisms underlying their execution. An application designed according the above mentioned principles seem successful in the reduction of energy consumption.

Abstract - Italiano

Numerosi studi hanno esplorato il ruolo dei fattori psicologici nella produzione di comportamenti pro-ambientali e di risparmio energetico. La “theory of planned behavior”, il “norm activation model”, e il “new environmental paradigm” hannno il fondamento teorico a un gran numero di studi in questo campo. Altri singoli fattori psicologici che sono stati mostrati interagire con la produzione di comportamenti pro-ambientali sono l'esposizione alle norme sociali, i valori e motivazioni pro-ambientali, il coinvolgimento emotivo, il “locus of control”, e la conoscenza e consapevolezza delle problematiche ambientali.

Solo alcune delle decisioni pro-ambientali vengono tradotte in comportamenti, mentre altre non vengono messe in atto. Ad esempio alcuni comportamenti pro-ambientali richiedono adeguate infrastrutture. Le norme personali diventao attive in seguito alla comparsa di stimoli situazionali. Inoltre, il divario tra intenzione e comportamento è mediato dalla stabilità temporale delle intenzioni, dal controllo percepito sul proprio comportamento, e dalla costruzione di intenzioni di implementazione.

Due studi recenti hanno mostrato come le funzioni esecutive mediano il divario tra intenzione e comportamento per l'attività fisica e il comportamento alimentare. Abbiamo ipotizzato che quando i comportamenti di risparmio energetico comportano un carico dei processi cognitivi sottostanti, l’efficienza di queste funzioni (in particolare l'efficienza delle funzioni coinvolte nel controllo dell’azione) medi la produzione dei comportamenti di risparmio energetico. Per verificare questa ipotesi abbiamo condotto tre esperimenti. Nel primo abbiamo

esaminato la relazione tra di memoria di lavoro, velocità di elaborazione, e l'attenzione sostenuta con la produzione dichiarata di comportamenti di risparmio energetico. I risultati suggeriscono che l'efficienza delle funzioni sopracitate sia collegata alla produzione di comportamenti di risparmio energetico che richiedono un carico cognitivo per essere messi in atto nella routine quotidiana. Nel secondo esperimento abbiamo esaminato il ruolo della memoria di lavoro, della velocità di elaborazione e dell'attenzione sostenuta sulla produzione osservata di un comportamento di risparmio energetico, spegnere la luce quando si esce da un laboratorio. In questo caso, la relazione non è risultata significativa, probabilmente perché alcuni partecipanti si sono astenuti dall'eseguire il comportamento di risparmio energetico perché non si sono sentiti autorizzati ad interagire con l'attrezzatura del laboratorio. Quindi, nel terzo esperimento abbiamo creato questa "autorizzazione" chiedendo ai partecipanti di accendere alcuni apparecchi posti all'interno del laboratorio all'inizio della sessione sperimentale. Attraverso un paradigma di doppio compito abbiamo esaminato il ruolo del carico dell'centrale esecutivo nella produzione di comportamenti di risparmio energetico. I risultati mostrano che un'interferenza con il sistema esecutivo centrale (i.e., la generazione di numeri casuali) diminuisce la produzione dei comportamenti di risparmio energetico non collegati con un evidente stimolo ambientale.

Il feedback viene spesso utilizzato negli studi psicologici mirati a ridurre il consumo energetico. Il feedback agisce come auto-insegnamento poiché permette agli utenti di imparare dalla loro esperienza e dalle conseguenze dei loro comportamenti energetici. Precedenti ricerche hanno mostrato che il feedback è più efficace quando è immediato, trasmette poche informazioni, ed è relativo ad un obiettivo dell'utente. Nel progetto BeAware abbiamo sviluppato un'applicazione (i.e., EnergyLife) per aiutare gli utenti a ridurre i loro consumi attraverso un sistema di feedback mobile basato sul cellulare. EnergyLife include un livello comunitario per offrire un clima di concorrenza cooperativa ed un obiettivo sociale per massimizzare l'effetto del feedback. Il feedback fornito da EnergyLife era in tempo reale. Inoltre, agli utenti sono venivano inviati dei messaggi persuasivi (sia generici che smart/ context-aware). L'efficacia dell'applicazione EnergyLife è stata valutata attraverso uno studio che ha coinvolto 5 famiglie e 14 utenti. L'analisi sui trend del consumo di energia ha mostrato una significativa riduzione dei consumi per tutte le famiglie. Nel complesso, le famiglie mostrano una significativa riduzione progressiva dei consumi rispetto all'anno precedente. Inoltre, quando un utente riceve uno smart advice (un messaggio customizzato sul suo comportamento) il consumo dell'apparecchio menzionato diminuisce.

Nel complesso, i risultati suggeriscono che la nostra comprensione dei comportamenti di risparmio energetico potrebbe essere migliorata considerando l'influenza dei meccanismi cognitivi alla base della loro esecuzione. Un'applicazione progettata secondo i principi sopra menzionati sembra essere efficace nella riduzione del consumo energetico.

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1. Environment

Since the late ’70s, environmental paybacks of energy consumption have become one of the major concerns of the public opinion. Changes in climate become one of the mayor environmental, political and economical issue; several looked at the reduction in energy consumption as the most feasible way to mitigate these changes trough the reduction of greenhouse gas emission (Alcott, 2012; but see Berg, 1974; Hammond, 1977; Hawes, Feldman, & Banu, 1993; Sarkanen, 1976). Each year, human energy production results in the emission of roughly 30-thousand-billion tons of carbon dioxide (EIA, 2008). An important quote of greenhouse gas emission is traceable back to the energy consumption of private households (Steg, 2008). For instances, in the 2003 private households were responsible for the 21% (i.e., 1214.8 million metric tons) of energy related carbon dioxide emission in the United States (US Department of Energy, 2011). In other Western countries, a similar trend can be observed. 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 CO2 emissions is expected to keep rising (Biesiot & Noorman, 1999): Since the ‘90 carbon dioxide emissions related to electricity use have increased by 2.4% each year (US Department of Energy, 2011). There is as strong variability between households energy usage, and each household uses energy for a large variety of purpose (Steg, 2008). In the UK, space heating is responsible for the 53% of household energy consumption, water heating for the 20%, lighting for the 6%, cooking for the 5% and other miscellaneous appliances for the 16% (DEFRA, 2006). The stabilization of greenhouse gas emissions requires a decrease in energy production, which provides an essential input to our economies: Cuts in energy production are likely to have significant economical, political and social cost. Thus energy saving through the reduction of wasted energy is important to mitigate the consequences (Smulders, 2003). Moreover, energy production come with a cost, thus energy saving has strong financial implications.

2. Psychology contribution to energy conservation

For decades, energy conservation has been a relevant area of investigation in technical-engineering field as well as in social and environmental psychology. In 1977, Hammond described the Brazilian government efforts to substitute oil with nationally produced alcohol. Yet, one year earlier Seligman and Darley (1976) had showed how the usage of informative feedback can successfully reduce households' energy consumption. Changes in energy use (i.e., energy saving) can be moderated by the effects of socio-demographic and psychological variables (see Kollmuss & Agyeman, 2002; Steg, 2008, for reviews). Although much attention has been given to efficiency, materials, and exploitation of renewable sources (e.g., Berg, 1974; Hawes, Feldman, & Banu, 1993; Sarkanen, 1976), today it appears clear that social and cognitive factors have an important role in energy saving (Midden & Ritsema, 1983). Psychological approach has given an important contribution through interventions based on the understanding of psychological mechanisms behind saving or wasting behaviors (e.g., Abrahamse, Steg, Vlek, & Rothengatter, 2005; Becker, 1978; Joule, Girandola, & Bernard, 2007; Midden & Ritsema, 1983; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007).

Gender and education are the two main demographical factors known to affect the environmental knowledge and the engagement in pro-environmental behaviors (see Kollmuss & Agyeman, 2002, for a review). Albeit women often show a less specific knowledge about how to perform pro-environmental behaviors, they seem to be more emotionally involved in the environmental issues (Fliegenschnee & Schelakovsky, 1998; Lehmann, 1999). People with a higher education show an increased environmental knowledge, yet education does not seem to affect the engagement engage in pro-environmental behaviors (Kollmuss & Agyeman, 2002).

Environmental psychology and social psychology have explored – often with a significant overlap – the roots of both pro-environmental behaviors and human energy consumptions. Environmental psychology focus on the study of the complex interactions between the humans and the environment they live in. The psychological basis of pro-environmental behavior, such as specific attitudes and personal norms form a consistent part of the area of interest of environmental psychology (Kollmuss & Agyeman, 2002). Social psychology brought an essential contribution to the research on energy conservation. For instances, social psychology provided several theoretical concepts and models used in the interventional studies based on feedback (Stern, 1992). Social psychology brought an important contribution to our understanding of the psychological basis of human environmental degradation and pro-environmental behavior, considering both the individual and the group as unit of analysis.

A number of studies have explored the reason why people act environmentally (or do not), and what are the barriers to pro-environmental behaviors. In fact, many people seem to set only a low priority to energy saving and other pro-environmental behavior (Steg, 2008). When people plan their energy use they are not focused only on saving concern and pro-environmental attitude: Several factors such as desired comfort, required effort and social status concur in determining the amount of energy used (Stern, 1992; Stern, 2000). Therefore is not surprising that the ways of reducing energy consumption that imply a high cost in terms of money, effort or impact on lifestyle are less likely to be adopted (see Lindenberg & Steg, 2007, for a review). Pro environmental activities that require a limited monetary and behavioral cost – such as recycling – are far more likely to be carried out than other activities that require a significant effort and change in lifestyle – such as reducing the frequency of car use (Steg, 2008). On the other hand, the point where in the cost-benefit trade off people opt for the pro-environmental behavior is specific for each person, and it is under the influence of a number of psychological factors. For instances, some highly motivated people would opt for an environmental behavior even when it implies a high cost and will drive to a significant personal disadvantage (Steg, 2008). In this section, we will briefly review psychological models and theories that explored the factors that influence the decision to engage in pro-environmental behaviors. Ajzen's (1991) theory of planned behavior and Schwartz's (1977) norm activation model are the theoretical frameworks at the base of most of the studies that explored pro-environmental behaviors (Abrahamse & Steg, 2009; Bonnes & Bonaiuto, 2002). Moreover, we will introduce other models that showed to be able to provide a significant contribution in the understanding of pro-environmental behaviors or in the reduction of energy consumptions.

1. Planned environmental behaviors

The theory of planned behavior is an example of rational choice theory based on the assumption that behavior is the result of a reasoned process of weighing costs and benefits of alternative actions (Ajzen, 1991). Cost and benefit can be expressed in terms of money, effort or expected social approval (Abrahamse & Steg, 2009; Ajzen, 1991). The intention to perform a behavior (i.e., behavioral intention) is considered the most proximal predictor of the production of the specific behavior (Ajzen, 1991). The intention to perform a behavior is considered to be determined by attitudes, perceived behavioral controls and subjective norms (Ajzen, 1991; Ajzen, Brown, & Carvajal, 2004). Attitude can be defined as the favorable or unfavorable evaluation that is given to an hypothetic behavior, depending on the reasoned weighting of expected cost and benefit implied (Ajzen, 1991). Perceived behavioral control can be defined as the perceived control on the possibility to successfully engage in the desired behavior (Ajzen et al., 2004). Subjective norms are determined by the perceived consequences that an action will have on the social environment (Ajzen, 1991). The theory of planned behavior has been successfully used to both explain and predict a wide range of behaviors ranging from dietary choice to voting decision (see Ajzen, 1991; Armitage & Conner, 2001, for reviews). In particular, the theory of planned behavior has proven to be effective to predict a number of pro-environmental behaviors, such as the choices in the usage of cars (Bamberg & Schmidt, 2003), buses (Heath & Gifford, 2002), energy-saving light bulbs and unbleached paper (Harland, Staats, & Wilke, 1999).

2. Active environmental norms

The norm activation model (Liere & Dunlap, 1978; Schwartz, 1977) considers the pro-environmental actions a specific form of altruistic behaviors, where personal benefits have to be relinquished for the collective interests. Altruistic behaviors are believed to be induced by active personal norms: People acting in accordance with their active norms will experience a sense of pride, whereas people acting in conflict with their active norms will experience a sense of guilt (Schwartz, 1977). A personal norm must be activated in order to influence the person's behavior; the activation itself depends on two main requirements. Before a personal norm is activated people have to be aware of the consequences of their behavior (i.e., awareness of consequences; Abrahamse & Steg, 2009). As well, people have to feel responsible for the consequences of their behavior (i.e., ascription of responsibilities; Abrahamse & Steg, 2009). Therefore, people have to be aware of the consequences that their behavior has on the environment and to feel responsible for them. People that feel personally responsible for the environment and believe that the consequences of their environmental actions are important, will activate norms that will push them to contribute to the solution of the environmental issues by reducing their energy use (Abrahamse & Steg, 2009). In fact, the norm activation model has been successfully used to explain the engagement in a number of pro-environmental behaviors, such as in recycling and energy conservation (Black, Stern, & Elworth, 1985; Guagnano, Stern, & Dietz, 1995; Hopper & Nielsen, 1991).

3. Social norms theories

A social norm is defined as an expectation shared by a group that specifies the behavior that is considered appropriate for a given situation (Backman, Secord, & Pierce, 1963). Pro-environmental campaigns based on descriptive social norms are aimed to reduce the undesired behaviors by conveying the concept that those behaviors are occurring less often than most people think. On the other hand, for individuals who already withhold from the targeted behavior such normative information can produce a boomerang effects, "authorizing” them to indulge in these behavior that now they see are more common than they expected (Schultz et al., 2007). According to the theory of normative conduct (Cialdini, Kallgren, & Reno, 1991), the injunctive norm is a specific type of social norm that, as the descriptive norm, has a powerful influence on behavior. Whereas descriptive norms refer to the perception of what is commonly done in a given situation, injunctive norms refer to the perception of what is commonly approved or disapproved within the culture (Reno, Cialdini, & Kallgren, 1993). But what happen if there is incoherence between descriptive and injunctive on the prescribed behavior norms? The focus theory of normative conduct states that even if only one of the two types of norms is prominent in an individual’s consciousness, this will influence on the behavior (Cialdini & Goldstein, 2004). Thus, in situations in which descriptive normative information may normally produce an undesirable boomerang effect an injunctive message supporting the desired behavior might prevent that result. The results emerged from a campaign conducted by Schultz et al. (2007) resulted to be consistent with predictions derived from the focus theory of normative conduct (Cialdini et al., 1991).

Descriptive normative information had a considerably different effect depending on whether the consumers were initially above or below the average level of energy consumption in their neighborhood. Descriptive normative information persuaded the high energy consuming households managed to reduce energy consumption; in contrast for low energy consuming households the same descriptive message lead an to increasing of energy consumption. Yet, adding an injunctive component to the descriptive message proved to prevent this boomerang effect on low-consuming households. Instead, the positive effects of normative messages continued to be significant even 4 weeks after the initial intervention. This suggests that is important to integrate descriptive messages with injunctive norms. In fact, even if campaigns are aimed at individuals whose behavior is less desirable than the norm (i.e., high consumers), the widespread nature of these campaigns nearly ensures that people whose behavior is "better than the norm" will also receive the message, thus is important to act in advance to prevent this boomerang effect (Schultz et al., 2007).

4. Social identity theory

Social identity theory (Tajfel & Turner, 1979) assumes that people perceive their membership in a group as a part of their own identity, and they will in general strive to gain a positive self-image. Stressing the common group identity can led to an increase of cooperative behaviors, even when there is no corresponding compensation in terms of individual benefits (Wit & Wilke, 1988). The theory of social identity gained a strong consideration in the designing of normative feedback. In fact, comparative feedback seems to emphasize the identification of the people with their own group. Moreover, the information about the outcomes of other groups leads to competitive feelings and a striving for better performance. Siero, Bakker, Dekker and Van der Burg (1996) explored the effectiveness of comparative feedback in an experiment that took place in two separate branches of a metallurgical company. In one unit, employees received information about energy conservation, had settled goals and received feedback on their own conservation behavior. The same procedure was implemented in the second unit, but the employee also received information comparing their performance with their colleague of the other unit. The results clearly showed that employees in the comparative feedback condition saved more energy than employees who only received information about their own performance. Another studies showed that the competition between groups of household can enhance the learning and increase the interactions between individual in the groups (Darby, 2006). Still, the direction of the comparative feedback – which is not possible to control beforehand – can sometimes act as a complicating factor during the intervention. That is, when people in a group perform better than the others they remain motivated and will devote themselves to the group goal. In this case, subjects can sustain a positive self-image by the information obtained from feedback. When a person is member of a group that performs worse than the comparison groups, they will usually attempt to improve their performance in order to maintain a positive identity. On the other hand, in the case of a continuously bad performance the comparative feedback can also have negative effects. Under competitive conditions, people tend to avoid comparisons with others who perform better (Dakin & Arrowood, 1981; Van Knippenberg, Wilke,

& De Vries, 1981); this could lead to a de-investment toward both the group and environmental topic in general.

5. New environmental paradigm

As previously discussed, the relationship between our worldviews and our behavior is not strong: "behavior-specific beliefs mediate the relationship between worldviews and behavior" (Steg, Dreijerink, & Abrahamse, 2006). New environmental paradigm focus on the conception of beliefs about humanity's ability to upset the balance of nature, on the existence of limits to the growth for all human societies, and on humanity's right to rule over the rest of nature. New environmental paradigm assumes the existence of three main orientations that guide our behavior: an egoistic value-drive orientation, which leads people to try to maximize their individual outcomes, an altruistic orientation, which drive people to act to the benefits of other human being, and a biospheric (or ecocentric) orientation that express the human concern about environment and non-human being. New environmental paradigm is an extension of the value belief norm theory of pro-environmental behaviors (Paul C. Stern, 2000). Value belief norm theory is focused on the relationship between the humans and the environment they lives in. This relationship have a strong effect on specific beliefs about consequences on environment of human behaviors, as well it plays an important role in determining the perceived individual responsibility and the production of corrective actions. Value-belief-norm theory assumes that there is a casual relationship between the awareness of consequences and the following ascription of responsibility. New environmental paradigms further states that both awareness of consequences and ascription of responsibility depend form general environmental beliefs and the stability of their orientations. Moreover, new environmental paradigms assign an important role to personal norms: when a pro-environmental behavior is strongly supported by a personal norm people will also support new policies aimed to support the environment. Thus, personal norms mediate the relationship between ascription of responsibilities and the following acceptance of energy saving policies.

6. Cognitive dissonance

The central assumption of cognitive dissonance is that when people have beliefs and habits that are not consistent with each other will experience negative emotions that will produce an effort to reduce the dissonance (Festinger, 1957). Kantola et al. (Kantola, Syme, & Campbell, 1984) achieved a reduction in consumptions of the 12% respect to a feedback control group, exposing participants to the pre-existing dissonance between their declared attitude (i.e., the importance of energy conservation) and their actual behavior (i.e., an actual high level of energy consumption). Feedback and additional tips on energy conservation were provided to all participants, but the exposition of the cognitive dissonance resulted to utterly decrease the consumptions. On the other hand, it is possible that using a wrong approach while making explicit the conflict between the energy saving attitude and the actual energy wasting behavior the exposed dissonance could lead to a drop of the pro-environmental attitude.

7. Environmental knowledge and awareness

Most of the researchers agree that the lack of environmental knowledge is not responsible for a meaningful part of energy waste (see Kollmuss & Agyeman, 2002, for a review). Yet, several misconceptions on the details of energy consumption are quite common, such as about how much energy is used by each device (see Steg, 2008, for a review). When asked to estimate the usage of an appliance, users tend to attribute more consumption to larger appliances (Baird & Brier, 1981). Consumers underestimate the amount of energy that is required to warm up the water. Some neutral or pro-environmental behaviors can lead to environmental degradation when the relevant circumstances change. For instance, in China, people were used to throw out of the window their food packaging when travelling on train. Even if previously this behavior did not have consequences against the environment, being the packaging made of clay, the introduction of paper and plastic packaging turned this habit into an environmental issue (Preuss, 1991). Knowledge of the environmental consequences of a specific behavior have to be modified when the circumstances changes.

Environmental awareness can be defined as “knowing the impact of human behavior on the environment” (Kollmuss & Agyeman, 2002). Three main cognitive limitations can constrain the consolidation of environmental awareness. The first is the difficulty in having a direct experience of the majority of environmental problems. In fact, most of the consequences of environmental degradation are not perceivable (Preuss, 1991). For instance, global warming, pollution, greenhouse gas emissions can not be experienced directly. Even consequences that are be observable, such as the increase of sea level and the loss of biodiversity, often pass unnoticed. Usually the information about environmental degradation have to be converted in another format to be perceivable (e.g., a chart showing the increase of the global temperature). Then the information presented in this way will be linked more with the intellectual understanding than with the emotional experience (Preuss, 1991). The greater support that the environmental campaigns aimed to protect specific species (e.g., whales) receive much respect to those who are aimed to more abstract concept, such as environmental warming suggest importance of the emotional reaction towards the environmental degradation (Kollmuss & Agyeman, 2002). The second cognitive constraint is the slow and gradual nature of environmental degradation (Preuss, 1991). Our cognitive system is structured to perceive strong, drastic change but tends to ignore or to give less importance to slow, gradual modifications. The third cognitive barrier is the complexity of the problems at the base of environmental degradation. People tend to build a simplified view of environmental issues, this can constrain the development of a deeper understanding of environmental problems which might lead to an underestimating perception of the problem.

8. Emotional involvement

Emotional involvement can be defined as the strength of the affective relationship with an object, in this case the natural environment. According to Chawla (1999), emotional involvement towards environmental conservation plays a key role in determining our relative values and attitudes. Moreover, emotional involvement determines the emotional reaction we experience. In fact, a strong emotional reaction to environmental degradation makes more likely that the person will produce pro-environmental behavior to try to compensate (Grob, 1991). The experienced emotional reaction becomes stronger when we have a direct experience of environmental degradation (Chawla, 1999; Newhouse, 1990). It has been observed that women tend to show a stronger emotional reaction when confronted to environmental degradation (Grob, 1991; Lehmann, 1999). However, why some people become emotionally involved whereas others do not? The lack of environmental knowledge or awareness can be a reason for emotional de-involvement. For instances, the difficult in perceiving the environmental degradation can also result in lack of emotional involvement. To experience an emotional reaction towards abstract, complex or not directly perceivable issue can be regarded as an ability that have to be learned (Kollmuss & Agyeman, 2002). The knowledge of what provokes environmental degradation and its effects are a prerequisite for experiencing an emotional involvement. Information have to be conveyed in the appropriate form to result in an emotional involvement (Fliegenschnee & Schelakovsky, 1998; Preuss, 1991). Moreover, people tend to resist to information that are not conforming to their habits or beliefs (Festinger, 1957). Cognitive dissonance theory states that people seek consistency in their mental frameworks and select preferentially those information that support their already existing values and are coherent with behaviors and habits. In turns, people tend to avoid those information that would create a contrast with current values or beliefs. Thus, information that conflict with our basic assumption of lifestyle, material needs or quality of life might be disregarded. In addition, different emotional reactions have different probabilities to trigger pro environmental behavior (see Kollmuss & Agyeman, 2002, for a review). The most common emotional reaction to environmental degradation are guilt, fear, sadness and anger. People experiencing fear, sadness, pain, or anger might be more likely to engage in pro-environmental behavior than people experiencing guilt.

9. Values and motivations

Values are goals that are not specific to a situation and express what is important in the life of a person (Schwartz, 1992). Values can be described as concepts or beliefs guiding the person when is evaluating a behavior, an attitude, a goal or an event (see Maio, 2010; Roccas & Sagiv, 2010, for recent reviews). Values are considered responsible for shaping much of our motivations. In turns they receive a strong influence from the immediate social net, such as family, peers, etc. (Fuhrer, Kaiser, Seiler, & Maggi, 1995). The cultural system in which a person lives also provide an influence, albeit less strong, to a person's values (Fuhrer et al., 1995). Chawla (1999) explored the reasons and the experiences that lead to the development of strong pro-environmental values in environmental activist in United States and Norway. She found that most commonly there is no single experience that determines the construction of strong pro-environmental values, but they emerge from the interactions of a number of factors. The most common types of experiences are experiences in nature during childhood, direct experiences of environmental degradation, the presence of strong pro-environmental values in the family, experiences within environmental association, education and example form significant figures (e.g., friends and teachers).

Motivation can be defined as the concept used to explain the reason of a behavior or as the strong internal stimulus around witch behavior is structured (Wilkie, 1990). Motivations can be described in terms of intension and direction (Mitchell, 1982) and can be both conscious and unconscious (Tamir, 2009). Another distinction can be made between primary and secondary motives: “A secondary motive is based on another motive while a primary motive lacks such a basis” (Oppenheimer, 1947). Contrasting motivations can be used to describe both the refraining and the production of pro-environmental behaviors: Contrasting motivations are a common barrier to pro-environmental behavior, which can be overridden if the non-environmental motivation is more intense (Kollmuss & Agyeman, 2002).

10. Locus of control

People who experience strong feelings toward environment combined with a perception of helplessness are not likely to engage in pro-environmental behaviors. Locus of control can be defined as the subjective perception of the possibility that a person has to create an effective change through their actions (Phares, 1976). Internal locus of control is the belief that our own action determines the course of a specific situation. In turns, external locus of control is the belief that our own action do not play an important role in determining the outcome, which is under the influence of external forces (e.g., other people or luck). People that puts an external locus of control on environmental degradation are much less likely to engage in pro-environmental behaviors, since they believe their action do not provide a significant contribution to the courses of the events (Hines, Hungerford, & Tomera, 1987).

3. The gap between environmental concern and actual behavior

Most of the people are aware of the environmental and financial cost of domestic energy consumption, and report to be concerned by this issue (Abrahamse, 2007). In a recent article Steg (2008) 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”. The gap between saving intention and behavior is an important issue to when designing an effective psychological intervention on energy conservation. Early psychological approach to energy conservation focused on consumer information, individual attitudes or beliefs, and the effect of financial incentives (see Stern, 1992, for a review). Nevertheless the gap between the environmental concern and the actual behavior (e.g., Kantola, Syme, & Campbell, 1984) can obstacle an intervention based on environmental awareness (Kollmuss & Agyeman, 2002). For instances, Preuss (1991) made a distinction distinguishes between the “abstract willingness to act” which considered based on personal values and knowledge and the “concrete willingness to act” which is based on habits (Preuss, 1991). In fact, intention does not always predict behavior: Several factors have been shown to affect the realization of intentions. These factors include the perceived behavioral control (Armitage & Conner, 2001), the implementation intentions (Gollwitzer, 1999), the temporal stability of intentions (Conner & Godin, 2007; Conner, Sheeran, Norman, & Armitage, 2000), and the demographics or knowledge barriers (Kollmuss & Agyeman, 2002). Generally, perceived behavioral control and attitudes tend to be most strongly related to behaviors and intentions, whereas the link between subjective norm and behavior is weaker (Armitage & Conner, 2001). Altruistic behavior is believed to be determined by personal norms that have to be activated through situational cues provided by the context or by the example of others (see Biel & Thøgersen, 2007, for a review). Availability of products and services, infrastructure, cultural norms and economic factors affect the ability to implement a saving behavior (Steg, 2008). In this section, we will review the main factors that have been shown to mediate the relationship between pro-environmental dispositions and actual behaviors.

1. Perceived behavioral control

The theory of planned behavior states that behavior can be predicted by both intentions to perform it and the perception that the behavior is within personal possibilities (i.e., perceived behavioral control). Perceived self-efficacy refers to the beliefs over the personal ability to plan and execute the actions required to achieve a goal, this is not determined by the skills a person has but by their perception or what they will be able to do under the expected range or circumstances (Bandura, 1997). Especially when effort plays a key role in the reasoned weighting of cost and benefits, the person is likely to have independent levels of perceived behavioral control over the possibility to perform or not perform an intended behavior. Then this will influence both the intention to perform a behavior and the probability to produce it (Richetin, Conner, & Perugini, 2011). In brief, perceived behavioral control is the estimated personal capability to execute the set of behavior required to achieve a goal under a specific circumstances (Rodgers, Conner, & Murray, 2008). Perceived behavioral control has been successfully used to predict engagement with fitness and physical activity in patients with a coronary syndrome event one year after the end of hospitalization (Allan, Johnston, Johnston, & Mant, 2007). Other studies showed that perceived behavioral control can predict the physical exercise intentions in in patients with coronary heart disease (Godin, Valois, & Lepage, 1993) and the actual exercise in patients recovering from cancer (Courneya & Friedenreich, 1999).

2. Temporal stability of intentions

Temporal stability of intention can be defined as the absolute change over time of any measured individual intention (Conner, Norman, & Bell, 2002). To predict the behavior an intention has to remain reasonably stable over time, at least until the behavior is actually performed (Ajzen, 1996). In fact, when intentions are assessed before the behavior these can latter change in response to events occurred meanwhile, thus turning the direction of the behavioral intention. In fact, temporal stability of intention is a requirement for the use of the theory of planned behavior to create accurate predictions (Ajzen, 1991). Temporal stability of intention can be considered a key indicator of intention strength (Sheeran & Abraham, 2003) that is affecting the “gap” between intention and behavior.

The moderating role of temporal stability of intentions on intention behavior gap has been addressed in a number of recent studies on healthy behaviors (se also Doll & Ajzen, 1992; Sheeran, Orbell, & Trafimow, 1999, for earlier studies). Intention stability moderates the effect of the intention to both attending a health screening and following a low fat diet over a 3 month period (Conner et al., 2000). Moreover Conner et al. (2002) showed a similar moderator effect of the stability of intention for eating behaviors even over a period of 6 years. When intentions were stable over time, they resulted to be a stronger predictor of behavior. Intentions stability has been shown to have a moderation effects for the initiation of smoking (Conner, Sandberg, McMillan, & Higgins, 2006). When intentions were stable, they resulted to be more predictive than the past behavior on the subsequent actions (Sheeran et al., 1999), in this case to study over the winter vacations. Furthermore, the results indicated that the temporal stability of intention is crucial to a successful performance when a person has a positive intention to perform a behavior. Sheeran and Abraham (2003) showed that temporal stability of intentions can as well mediate the effect of a number of different moderators (e.g. anticipated regret, certainty, etc.) on the gap between intention and behavior.

3. implementation intentions

Implementation intentions are formed when a person strive to obtain a goal (Webb, Sheeran, & Luszczynska, 2009). Implementation intentions relies on then formation of if-then plans, establishing an association between anticipated situation and response that is similar the situation-response relationship in habitual behavior (Gollwitzer, 1993, 1999; Gollwitzer & Sheeran, 2006). When person are asked to form a concrete if-then plan reasoning on when and how to carry out the appropriate behavior the "gap" between intention and behavior is dramatically reduced (see Gollwitzer, 1999; Gollwitzer & Sheeran, 2006, for reviews). When implementation intentions are formed, they lead to a sense of commitment to act consequently (Gollwitzer, 1999). Still the main component of their effect is to transfer the control of the behavior to the cues and stimuli provided by the situation (Gollwitzer, 1999). Using implementation intention people can turn to automatic behavior control, mediated by situational cues, instead of relying of the conscious and effortful control of action (Gollwitzer, 1999). In fact, when an implementation intention is constructed it creates a mental representation of the relevant situation and permanently associated it to the intended action, so that when the situation occurs the intended action is executed automatically bypassing a conscious decision (Ajzen, Czasch, & Flood, 2009). Implementation intentions increase the vigilance towards the critical situational cues (Gollwitzer, 1996) and improve their detection and the memorization (Aarts, Dijksterhuis, & Midden, 1999).

4. Economical and institutional factors

Several pro-environmental behaviors require the support of adequate infrastructures to be implemented (see Kollmuss & Agyeman, 2002, for a review). For instances, an effective waste disposal system is necessary to recycle domestic waste, or an adequate public transport organization is required to make possible the reduction of the use of cars. Moreover, an inefficient infrastructure increase the effort required by pro-environmental behaviors, thus decreasing the probability of the decision to perform it (Kollmuss & Agyeman, 2002). Psico-economic studies showed that people apply a 50% interest rate when deciding whether to buy an energy efficient device or not. That suggest that people will feel motivated by the economical aspect of buying an energy saving device only when the payback time is very short (see Kollmuss & Agyeman, 2002, for a review).

5. A role for cognitive functions?

In the 1991 Preuss explored the difference between the “abstract willingness to act” which he considered to be based on knowledge and values, and the “concrete willingness to act” which he considered to be based on habits. Recent studies suggest that the realization of intentions is also mediated by the cognitive processes that underlie the desired behavior. Executive functions efficiency predicts the achievement of dietary goals (Allan, Johnston, & Campbell, 2011). As well, the individual differences in the ability to inhibit the responses (and behavior) moderate the intention-behavior gap for physical activity and dietary behavior (Hall, Fong, Epp, & Elias, 2008). Yet, to the best of our knowledge, no study has explored the role of cognitive functions that support the execution of saving behaviors on this relationship. In fact, a number of saving behaviors can stress the cognitive processes that are necessary in order for us to execute such behaviors. For instance, switching off the lights when leaving a room implies 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?”), and it might require 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 potentially distracting events. A failure of the required cognitive processes might hinder the execution of saving behaviors, and might result in energy wasting even in the presence of saving intentions.

4. Experiment 1

1. Introduction

In this experiment, we will explore the class of energy saving behaviors that seem to depend on supporting cognitive functions as (i.e., cognitive effort based saving behaviors). Yet, it is often the case that the saving behavior does not imply an additional cognitive effort beyond the opposed wasting behavior, or that the wasting behavior is performed purposely. For instance, the choice to purchase an energy-efficient washing machine hardly relies on the cognitive control of our behavior. When energy is intentionally wasted, as when we switch-on the lights to prevent stealing in the case we are out of home, the execution of the intended behavior might rely on the underlying cognitive processes, but a lapse would not increase energy consumption. In this case, our actions might be explained by social norms or by standard decision making processes irrespectively of the efficiency of the involved cognitive functions. We referred to this category of energy conservation behaviors – that not imply the cognitive effort to monitor action routines – as choice based saving behaviors. The comparison between the two types of saving behavior is depicted in Figure .

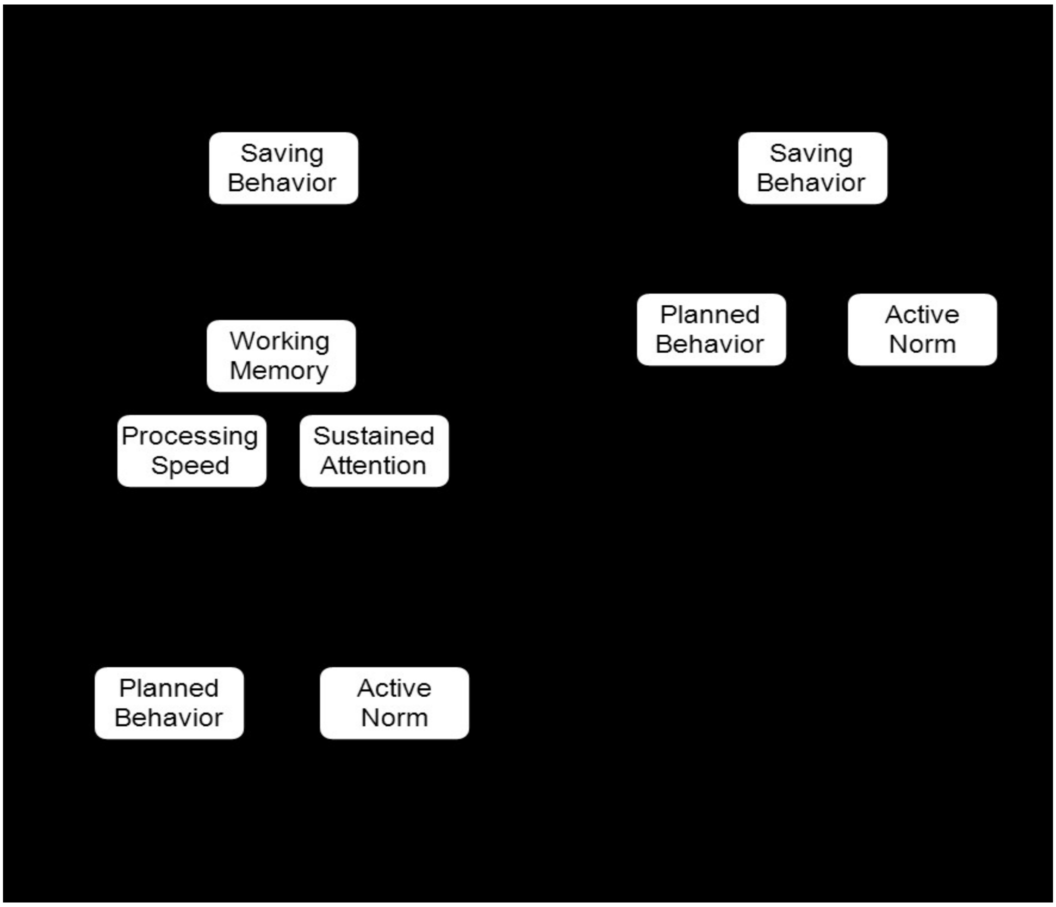


Figure . Schematic description of models of cognitive effort based saving behaviors and choice based saving behaviors. Critical steps are evidenced by dashed lines.

We hypothesized that sustained attention, speed of processing, and working memory could support the execution of cognitive effort based saving 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" (I H Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). A transitory reduction in attention allocated towards a cognitive effort based saving behavior might twist it into a wasting action (e.g., an interruption while we are about to put food into the fridge, would extend the time that the fridge's door remains open). In studies on healthy participants and brain-damaged patients, Robertson et al. (1997) showed that sustained attention is strongly related to everyday cognitive lapses. Fast processing of environmental input speed is inversely related to the number of undetected errors, when participants perform a skilled cognitive task (Bell & Gardner, 1997). Two subsystems of working memory might play a key role in the execution of cognitive effort based saving behaviors. Baddeley (1986) equated the central executive subsystem to Norman and Shallice's (1986) Supervisory Attentional System (SAS). The SAS is responsible for the activation of a specific thought or behavior schema by allocating attention to it. In fact, working memory might share a common underlying attentional component with the executive system. A recent study showed, indeed, that executive functioning is correlated both with working memory capacity ($r = 0.97$) and with speed of processing ($r = 0.79$; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). 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 (see Baddeley, 2002, for a review). 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

(Tombaugh, 2006). In fact, performance on the PASAT seems to be sensible to the cognitive mechanisms underlying the everyday execution of routines and complex behaviors. Robertson et al. (1997) have showed that errors on the PASAT are strongly correlated with everyday cognitive failure in brain-damaged patients. The aim of the present study was to investigate the relation between cognitive effort based saving behaviors and choice based saving behaviors and cognitive mechanisms supporting their execution (i.e., working memory, speed of processing, and sustained attention). To this aim, we investigated the relations between the PASAT and two ad-hoc constructed scales for measuring saving behaviors. We hypothesized that the extent of participants involvement in cognitive effort based saving behaviors would be related to the efficiency in their underlying cognitive processes, whereas choice based saving behaviors would not be related to the cognitive processes that we explored here.

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 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 brought special attention to inform the participants of their right to withdraw their participation in 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, 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 answer 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 motivational factors involved in energy conservation. The main section of the questionnaire was composed by 18 three-choice items oriented to investigate the frequency of daily energy-related behaviors (i.e., always, sometimes, never). To explore the two types of saving behaviors (i.e., choice based saving vs. cognitive effort based saving) the main section of the questionnaire was composed of two scales. The first scale included 12 3-choice items, which explored behaviors that take place after a cost-benefit evaluation and which did not stress the underlying cognitive mechanisms or purposely waste energy (i.e., choice based saving behaviors). Examples of items exploring the choice based saving were: "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 second scale included 6 3-choice items, which explored behaviors, where a specific effort of the supporting cognitive mechanisms could be pointed out (i.e., cognitive effort based saving behaviors). Examples of items exploring the cognitive effort based saving behaviors were "When I cook, I turn off the heating before the food is fully cooked in order to exploit the residual warmth" and "I leave the battery-charger plugged after the battery is loaded". To estimate the frequency of choice based saving and cognitive effort based saving behaviors we calculated the mean for the items in each scales by 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., relatively 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 engagement in saving behaviors.

3. Results

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 just "involved" in energy conservation. In fact, the reported frequencies of cognitive effort based saving and choice based saving behaviors were quite high: the mean score was 2.48 (SD = 0.25) for the cognitive effort based saving scale, and 2.64 (SD = 0.24) for the choice based saving scale. 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 system we computed a hierarchical multiple regression model between the score in

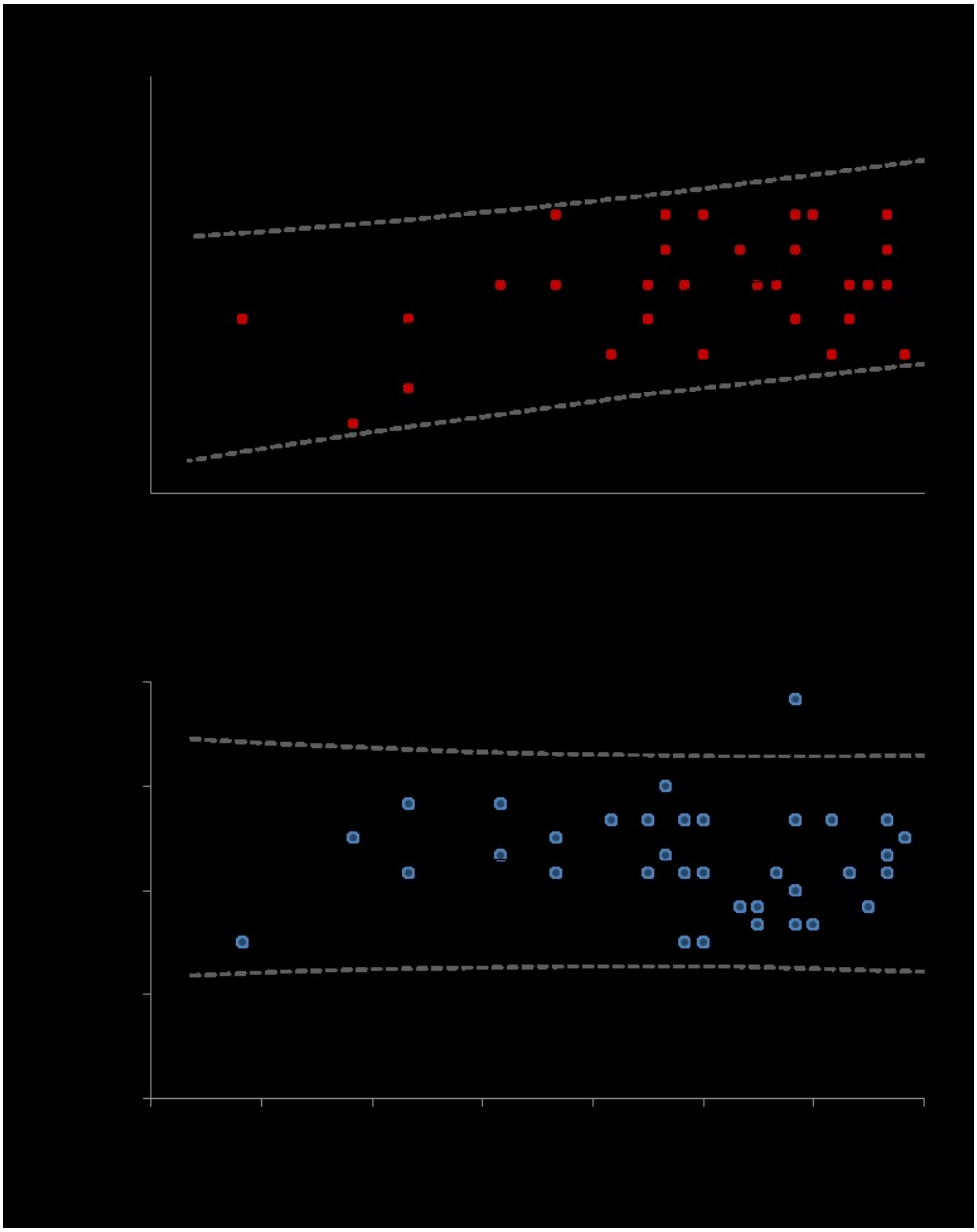


Figure . Scatter plot of the relationship between the performance on the PASAT and the involvement in energy saving. The relationship between accuracy on the PASAT and the cognitive effort based saving scale is shown in panel a, whereas the relationship between accuracy on the PASAT and the choice based saving scale is shown in panel B. Dashed lines represents the limits of 95 % prediction interval.

the cognitive effort based saving scale and the accuracy on the PASAT (see Figure , 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 the accuracy on the PASAT, were significantly related to the score in the cognitive effort based saving scale, β = 0.371, t(33) = 2.33, p = 0.02, whereas Education, β = -0.197, t(33) = -1.15, p = 0.26, and Age, β = 0.002, t(33) = 0.01, p = 0.99, were not. Accelerated bias-corrected confidence intervals for regression coefficients, obtained through 1000 bootstrap resampling, substantially confirmed the results of the regression analysis (see Table).

Table : multiple regression on cognitive effort based saving scale.

	b'	*t*(33)	*p*	BCa confidence intervals	
				Lower	Upper
Education	-0.197	-1.153	0.257	-0.4580	0.3377
Age	0.002	0.014	0.989	-0.3034	0.3843
PASAT	0.371	2.332	0.026	0.0922	0.7346

Note. N = 37, *b*' represents the standardized regression coefficient

After controlling for the effects of Age and Education, performance on the PASAT accounted for the 14% of the total variance in the cognitive effort based saving scale. With the choice based saving scale as the criterion variable (see Figure , panel B), the same regression analysis did not reveal significant effects of Education, β = -0.152, t(33) = -0.83, p = 0.41, Age (β = 0.145, t(33) = 0.79, p= 0.44), or the accuracy on the PASAT (β = -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).

Table : Multiple regression on choice based saving scale.

	b'	*t*(33)	*p*	BCa confidence intervals	
				Lower	Upper
Education	-0.152	-0.830	0.412	-0.3898	0. 4996
Age	0.145	0.787	0.437	-0.2376	0. 5133
PASAT	-0.017	-0.098	0.922	-0.4229	0.3172

Note. N = 37, *b*' 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 cognitive effort based saving behaviors. The accuracy on the PASAT explained a consistent quote of unique variance in the cognitive effort based saving scale (R2 = 0.14). 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 the efficiency of the cognitive system is less involved. Further studies are required in order to explore the specific contribution of each cognitive mechanism, and their interaction with norms, attitudes, and perceived behavioral control on determining energy saving efforts. 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" -represented by sustained attention, processing speed, and working memory capacity- might help explaining the frequently observed gap between positive attitude toward saving and actual energy consumption (e.g., Kantola et al., 1984). The waste of energy resulting from a cognitive failure should be targeted by psychological interventions (Abrahamse et al., 2005; Becker, 1978; Schultz et al., 2007). This could be achieved through designing appliances and devices that can decrease the cognitive load required by saving behaviors, thus, supporting their stable inclusion in daily routines. Overall, our results suggest that our understanding of energy conservation behaviors might be improved by considering the influence of cognitive mechanisms underlying their execution. 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; Ian H. Robertson & Garavan, 2004; Ian H. Robertson, Tegnér, Tham, Lo, & Nimmo-smith, 1995; Westerberg, Jacobaeus, Hirvikoski, & P, 2007). People involved in energy saving might benefit form a training of cognitive functions supporting the execution of saving behaviors, especially when implementing the desired behaviors during everyday life routines becomes difficult. In conclusion, 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 through a more effective psychological intervention this can lead to major financial and environmental benefits.

5. Experiment 2

1. Introduction

In previous study, we showed how a vast range of saving behaviors seems to rely on of working memory, processing speed and sustained attention. However, the measured engagement on energy saving behavior was based on the self-reported frequencies explored through a questionnaire. In fact, self-reports of conservation actions have shown to be only partially accurate (e.g., Hirst & Goeltz, 1985). Moreover, there seem to be an inconsistency between the reported frequency of a saving behavior and the traces in the autobiographic memory examined by aIAT (Gamberini, Sartori, Spagnolli, Ghirardi, & Martino, submitted). Thus, we designed a study to explore the relationship between working memory, speed of processing and sustained attention and the engagement in energy saving through a directly observed energy saving behavior. As saving behavior, we selected the action of turning off a light when leaving a room because of the simplicity of its reproduction in a laboratory context. Moreover, lighting accounts for almost on fifth of the electric energy consumption for the average household (DTI, 2006). Turning off a light is an action hat can involve the processing of the context (e.g., Are there other people in the room? How long will I stay away?) and might involve the interruption of an ongoing action or thought (e.g., leaving the room to answer the phone). In this study, we explored the relationship between the accuracy on the PASAT (i.e., a measure of sustained attention, speed of processing, and working memory) and the probability to turn off the lights when leaving the room. We hypothesized that participants will be more likely to turn off the light when leaving the laboratory.

2. Method

All participants provided written informed consent after the procedure had been fully explained according to the Declaration of Helsinki. Twenty-nine students (18 female; mean age = 22 yr, SD = 3 yr) took part to the study. Participants were recruited in the hall of the university. The researcher used a memorized written script to provide instructions and contact participants. Participants were contacted in the hall of the faculty and asked to participate to a brief study on their studying strategies. The researcher guided participants to the laboratory, which had its light off; the researcher turned on the light. Latter the researcher proceeded with the administration of the PASAT. At the end of the task, the researcher asked the participant to complete a filler questionnaire on studying habits. That was designed to provide to the participants a task involving their staying in the laboratory for about 20 minutes; the questionnaire was composed by 50 items. When the subject completed half of the questionnaire, the researcher left the laboratory mocking an urgent task received through SMS. Participants were thanked for the participation, and instructed to leave the material on the desk when they finished. We measured the engagement in energy saving behavior recording whether or not the participant turned off the light when leaving the laboratory. Researcher encountered the participants on the way out. participants were debriefed about the purpose of the experiment, and asked if they whished to consent to the usage of the collected data, or to withdraw their participation. Participants were informed that withdrawing their participation any collected data would have been destroyed. No participant withdrew the participation.

3. Results

On average, the 48% participants turned off the light when leaving the laboratory. Participants that turned off the light when leaving the laboratory had a better performance on the PASAT than participant that leaved it on (i.e., respectively an accuracy of .73 and .66). To model this dichotomous-choice data we used a linear logistic regression (Agresti, 2002). The probability of turning off the light when leaving the laboratory was related to the accuracy on the PASAT trough a logit linear regression model. Result shown that the accuracy on the PASAT was not a good predictor of the odds of turning the light off $z(27) = 1.13$ $p = .26$. The informal interview of the participants after the debriefing suggested that some of the participants leaved the light on by purpose, thus adding an unexpected error to the measure. In fact the distribution of the accuracy on the PASAT errors in the "on" is clearly abnormal: The scores showed a bimodal distribution, this suggests the presence of two populations within the group. In brief seems that the group of people that leaved the light on can be divided in people who forgot about it and people who willingly decided that was not appropriate to switch it off. Result form an affinity propagation cluster analysis on the Gower distance (Bodenhofer, Kothmeier, & Hochreiter, 2011; Gower, 1971) conducted over the accuracy on the PASAT and the production of the saving behavior were consistent with this interpretation.

4. Discussion

The results of present study are difficult to interpret. Strong conclusion can't be sustained by the unplanned cluster analisys or by the qualitative observation about the differen distributions of PASAT accuracy in people that leved the light on – turned that off. Yet the results are important at worst because they pointed out to two issues that might have hindered the effect. The first is used dependent variable, registered from a single observation. A great precision – thus power – might be achieved providing he opportunities for more saving behaviors. The second issue is the uncontrolled subjective feeling that participants had about the "authorization" to interact with the laboratory setting (i.e., turning off the light). A possible solution for the problem would be to ask to participant to switch them on at the beginning of the experimental session, to create for every participants an "authorization to interact" with the laboratory. Overall, results suggest that working memory, processing speed and sustained attention might predict the production of saving behaviors, but investigation with a different design is required to support this claim.

6. Experiment 3

1. Introduction

In the present study we explored the role of central executive component of working memory (Baddeley, 1986) in daily life energy saving behaviors. Baddeley (1986) equated the central executive subsystem to Norman and Shallice's (1986) Supervisory Attentional System (SAS) responsible for the activation of a specific thought or action schema by allocating attention to it. In fact the central executive plays a key role in action control (Baddeley, Chincotta, & Adlam, 2001). The three major central executives processes are inhibition of actions that conflict with the goal, shifting to the more appropriate task set or strategy, and updating information relevant to the task (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Our hypothesis is that carrying out daily life saving behaviors (e.g., switching off a device when not needed anymore) involves the contribution of central executive based cognitive process. For instances to perform a saving behavior we might have to update relevant information (e.g., "What devices I turned on?" or "Does somebody else need them?"), interrupt of an ongoing action (e.g., leaving the room to answer the phone) and shift between tasks (e.g., "stop writing a text to turn off the light"). Then a failure of the central executive, or other required cognitive processes, will hinder the execution of the saving behavior resulting in a waste of energy even in the presence of saving intentions.

In the present study, we used a dual-task paradigm to examine the role of central executive in daily life energy saving behaviors. We manipulated the central executive load to observe its effect on the occurrence of energy saving behaviors. To measure the effect of central executive load we created the opportunity for specific saving behaviors (i.e., turning off devices when are not used anymore) selected to be easy to reproduce in a laboratory. Central executive load was created asking participants to generate random number (Baddeley, 1986). Random number generation requires the switching between learned numeric sequences (Baddeley, 1986), the inhibition initiated sequence (Baddeley, 1996), and keeping track of recent responses to compare the next one to our conception of randomness (Jahanshahi et al., 1998). Instead of using a no-task control condition, we asked to participants to repeat a short fixed numeric sequence posing a minor load of verbal short term memory. We designed the control condition to match the experimental condition in instruction and interaction with participants. We hypothesized that participants in the executive load condition would be less likely to engage in an energy saving behavior than participants in the control condition.

2. Procedure

All participants provided written informed consent after the procedure had been fully explained according to the Declaration of Helsinki. Twenty-three students at the University of Padua participated to the study. The researcher used a memorized written script to provide instructions and contact participants. Participants were contacted in the hall of the faculty and asked to participate to a brief study centered on watching a video. Participants were randomly assigned to central executive load or control conditions and tested in individual sessions. The researcher guided participants to the laboratory and handed them the key. Participants opened the door and entered the laboratory first; they were asked to turn on the light (the switch was located on the wall left of the door), the lamp (on the table in the left-bottom corner), TV and DVD player (in the right-top corner). Participants sit on a sofa 1.5 m away from the television; researcher started the video (lasting ca. 5 minutes).

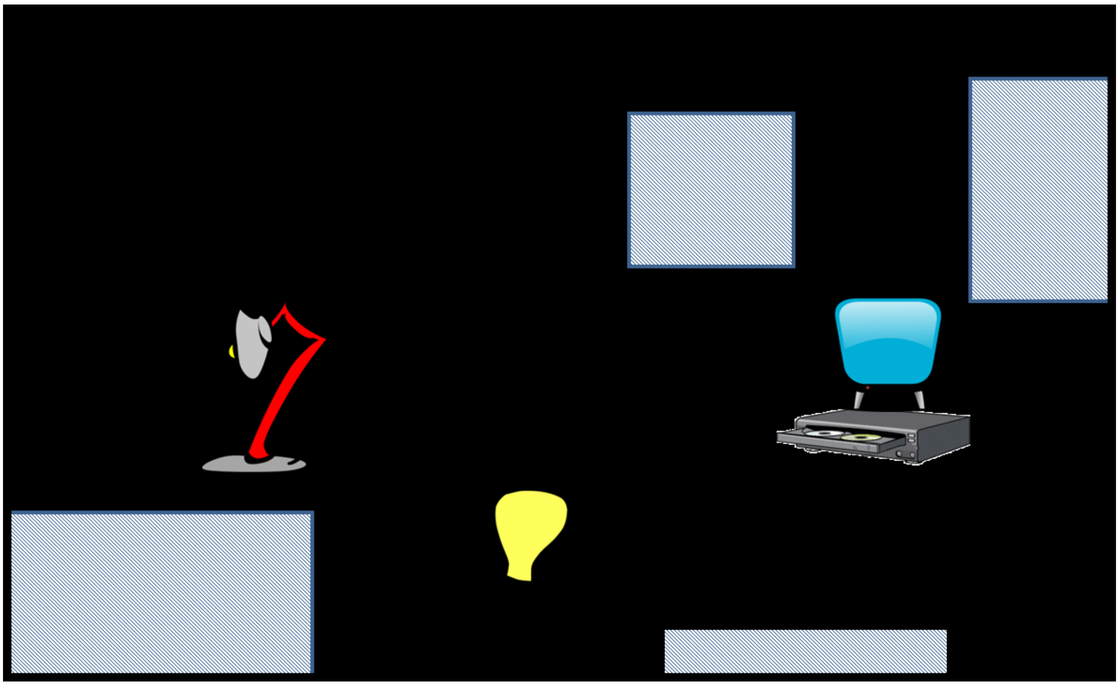


Figure . Schematic representation of the laboratory, in particular of the position of the light switch, the table lamp, the TV and the DVD player.

At the end of the video researcher asked them to perform the task specific to the experimental condition. Participants had to proceed autonomously for ca. 2 minutes and then to catch up with the researcher waiting in the corridor, for the continuation of the experiment in another laboratory. In the central executive load, condition participants were instructed to produce one random digit every ca. 1 second. In the control condition they were instructed to repeat a fixed numeric sequence (i.e., 6-5-3-9), at the same rate as the random number generation. In both condition the researcher left the laboratory as soon as the participant started producing numbers. Participants have been previously instructed to lock the door when leaving the laboratory and to pronounce numbers aloud without interruption unlit they rejoined with the researcher. We measured the effect of central executive load on saving behaviors trough the number of devices that participants turned off when leaving the laboratory. The execution of the task (i.e., random number generation – fixed sequence repetition) was recorded with a hidden video camera, also used to double check the saving behaviors actually performed. Four participants were dismissed prior to the data analysis. A participant prolonged the execution of the experimental task (to 10 min), the participant reported to enjoy the generation of random number in the laboratory. Other two were excluded because they interrupted the secondary task while in the laboratory. The last participant was excluded because a technical problem compromised the recording, making impossible to verify the correct execution of the task. Nineteen participants were included in the analysis. Nine participants (5 females) were assigned to the central executive load condition, 10 participants (6 females) were assigned to the control condition. In the second laboratory the researcher administered them a verbal short term memory test (Spinnler & Tognoni, 1987), a spatial short term memory test (Spinnler & Tognoni, 1987), PASAT (Gronwall, 1977; Stablum et al., 2007) and a short ad hoc questionnaire (see Table). The questionnaire included items about the video, ethical dilemmas related to the video content and three items about energy conservation. Participant were asked to rate on a 6-point Likert-type scale (1=strongly disagree/never, 6=strongly agree/always) the frequencies of forgetting lights on, the involvement in energy saving and the perception of energy saving as a personal duty. There was no significant difference in the performance on the neuropsychological tests or in the responses to the questionnaire between participants in the different experimental conditions.

Table : Characteristics of the participant groups.

	Executive load			Control			Total	
	mean	*SD*		mean	*SD*		mean	*SD*
Age	24.33	1.94		22.40	2.95		23.32	2.65
Spatial STM span	4.78	0.83		4.80	1.69		4.79	1.32
Verbal STM span	5.22	1.48		4.90	1.29		5.05	1.35
PASAT accuracy	0.69	0.19		0.59	0.16		0.64	0.18
I forget lights on	2.00	0.71		2.10	1.20		2.05	0.97
Energy saving is my responsibility	4.33	1.12		4.60	0.52		4.47	0.84
I am involved in energy saving	3.44	1.24		3.60	1.26		3.53	1.22

Note. Means and SDs for age (years), spatial short term memory span, verbal short term memory span, PASAT accuracy rate, reported frequency of forgetting lights on, reported involvement in energy conservation and judgment of energy conservation as a personal duty. Questionnaire items were self-rated on a 6-point Likert-type scale from 1 (strongly disagree/never) to 6 (strongly agree/always). Executive load group N = 9, Control group N = 10

At the end of the session, participants were debriefed about the purpose of the experiment, and asked if they wished to consent to the usage of the audio-video track, the audio track only, or to withdraw their participation. Participants were informed that withdrawing their participation any collected data would have been destroyed. Eighteen participants provided their consent for the audio-video track, one agreed to the usage of the audio recording only, none withdrew the participation.

3. Results

On average, participants turned off the 64% of devices when leaving the laboratory. Participant in the executive load condition turned off the 44% of the devices, whereas participants assigned to the control condition turned off the 82 % of lights (see Figure 4).

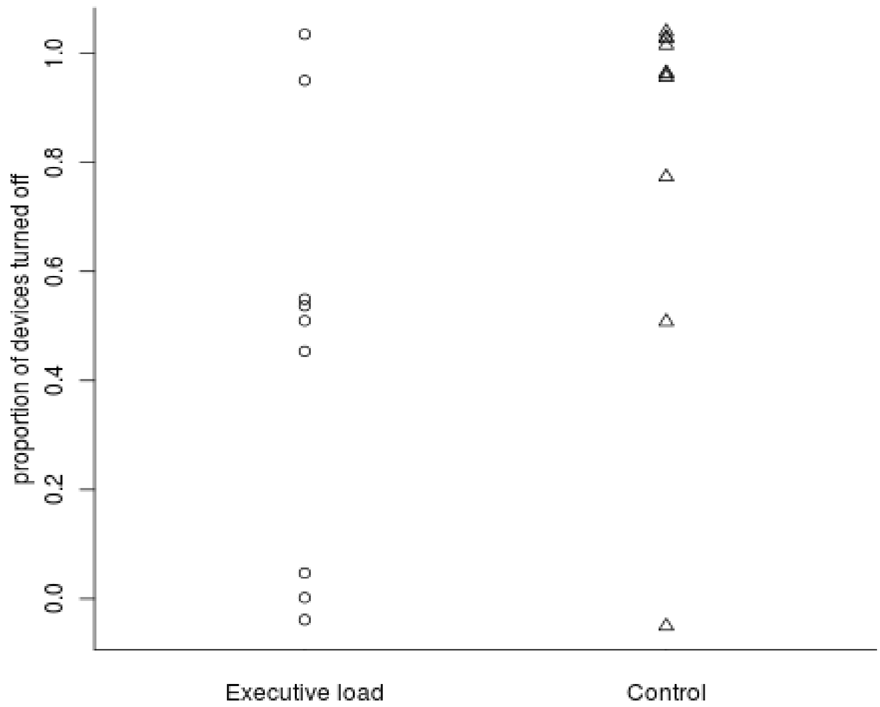


Figure . Scatter plot of the individual data, with the y-axis representing the experimental condition and the x-axis the proportion of devices turned off when leaving the laboratory.

To model this repeated dichotomous-choice data, we used a linear logistic regression (Agresti, 2002; Jaeger, 2008). The results confirmed the impression given by Figure . Central executive load significantly decrease the odds of turning off the devices before leaving the laboratory $\chi^2(1) = 10.503$ $p = .001$ $R^2_{Nagelkerke} = .44$. The effect of the executive load remained significant after controlling for the effect of age, sex, reported energy conservation habits-beliefs, and the scores at the neuropsychological tests $\chi^2(1) = 8.895$ $p = .003$ $R^2_{Nagelkerke} = .13$. Similar results were obtained using an independent sample t-test. Observing that the effect of executive load seem to varies across behavior (see Table) we conducted a separate analysis for each devices.

Table : Occurrence of saving behaviors.

	Executive load		Control
Turned off the light	0.67		0.70
Turned off the Lamp	0.67		0.80
Turned off the TV	0.25		0.89
Turned off the DVD player	0.22		0.89

Note. Percent of participants that turned off the devices divided per condition

Central executive load did not have a significant effect on the odds of turning off the light $\chi^2(1) = .024$ p = .876 $R^2_{Nagelkerke} = .00$. As well its effect on the odds of turning off the table lamp was not significant $\chi^2(1) = .435$ $p = .509$ $R^2_{Nagelkerke} = .03$. In turn, central executive load significantly decreased the odds of turning off the TV $\chi^2(1) = 7.759$ $p = .005$ $R^2_{Nagelkerke} = .49$ and the DVD player $\chi^2(1) = 8.917$ $p = .003$ $R^2_{Nagelkerke} = .52$.

4. Discussion

Results showed that central executive load decreases the probability of energy saving actions. Participants reported to be concerned with environmental issues, a finding consistent with prior research (Steg, 2008). When asked if they considered energy saving a personal duty most of participants agreed, and most of them reported to rarely forget lights on when leaving a room. On average participants reported to be moderately involved in energy conservation.

Participants in the central executive load condition turned off the 44% of the used devices, whereas participants in the control condition turned off the 82% of the devices, a difference of 38% ($R^2_{Nagelkerke}$ = .44). Observing that the effect of central executive load vary across devices we conducted a separate analysis for each one. While there was almost no difference in the probability of turning off the light between the two experimental conditions and only a non-significant 13% difference in the probability of turning off the table lamp, the probability of turning off TV and DVD player in the executive load condition decreased respectively of 64% and 66%. This suggests that the role of central executive system in energy saving behaviors varies across tasks. It is possible that some saving behaviors are triggered automatically by a cue that activates a well learned action schemas. An evident source of consumption (e.g., the illumination) might activate the appropriate energy saving behavior without competing for central executive resources. When a task set is already established the appropriate behavior can follow the cue without an "act of intention" (Logan, 1985): In fact well learned tasks can be performed automatically posing minimal attention demands. On the other hand, when saving behaviors is attentional demanding (e.g., requires the retrieval of information or action sequences) it has to be supported by action control processes. That is the case when there is no cue that can activate the saving behavior prior the allocation of processing resources, or the task is not automatized. Then we might have to explore the area, recall relevant information, inhibit irrelevant information or behaviors, and activate mental or behavioral actions trough supervisory attention system. Whereas in our study central executive contribution is associated with specific saving behavior it is likely that this association is context dependent. For instances turning off the light might involve the central executive when we have to interrupt an ongoing action (e.g., leaving the room to answer the phone) or the cue is less evident (e.g., because of alternative lighting source).

Further studies are needed to clarify the exact quantity of domestic energy consumptions that can be ascribed to the central executive. As well, other cognitive functions might be involved in domestic energy saving behaviors. For instance, other executive function and processes involved in action control (e.g., Posner & Petersen, 1990) are the most likely candidates to support daily life energy saving behavior. As seen before, processing speed and working memory (measured with PASAT) explained the 16% of variance in the reported frequencies of routine-based energy saving behaviors. In the interpretation of the results we assumed that the participants were willing to save energy. This assumption is consistent with the high percentage of devices turned off in the control condition and the responses to the items in the questionnaire.

Our findings suggest that energy conservation intervention (Becker, 1978; Midden & Ritsema, 1983; see Abrahamse et al., 2005, for a review) should target cognitive functions supporting energy saving behaviors. For instance, we could design devices that make improper use and consumption more evident. Then waste can be perceive without the need of allocating attentional resources users can use that "cue" to trigger automatically the learned saving behaviors. In conclusion, our findings evidence for the first time the role of central executive in energy saving behaviors thought an experimental manipulation of its efficiency.

The results are consistent with the hypothesis that the efficiency of involved cognitive functions might explain part of the gap between intention and behavior (e.g., Allan et al., 2011). In fact, our results suggest that a failure in the underlying cognitive processes can hinder the desired behaviors. Further studies on the role of central executive and other underlying cognitive processes could improve our understanding of daily life pro environmental behaviors. Moreover, an intervention reducing the cognitive requirement of pro-environmental behaviors can potentially lead to major financial and environmental benefits.

7. Design a mobile interface and field trial

1. How to use feedback

Feedback helps people to change their behavior acting on the perception of the consequences of people's actions (Abrahamse et al., 2005). Through feedback people can associate behavior to certain outcomes and increase their awareness on how they consume energy. Several of the psychological interventional studies on energy conservation are focused on feedback, which is considered as a tool for helping people in saving energy. Feedback can be defined as the "actions taken by an external agent(s) to provide information regarding some aspect(s) of one's task performance" (Kluger & DeNisi, 1996). These information will help people to fill the "knowledge-gap" that the great majority of residential energy show about their energy consumptions (Geller, Winett, & Everett, 1982). Feedback can be viewed as a "self-teaching tool" that makes energy consumption more visible and more enjoyable to understanding and control; feedback allows consumers to teach themselves trough experimentation of the consequences of their actions (Darby, 2006). According to Darby (2006) feedback, actions and information act in synergy to build "tacit knowledge" that is important for energy saving because as it grows, grows people's ability to seek and evaluate information, to solve problems and to share knowledge with others. In a recent meta-analysis Abrahamse et al. (2005) showed that the use of feedback resulted can successfully reduce energy consumption. In fact, most of the interventions achieved a decrease in household's energy use of about the 10%. When feedback was focused on shifting consumes out of peak it reduced the consumption form the 15% to the 30% during peak periods (Seligman & Darley, 1976). The installation of an electronic display of energy consumptions in 14 out of 31 participants lead to a reduction of consumptions above the 10% and for 6 of these households the reduction of consumptions exceeded 20% (Mansouri, Newborough, & Probert, 1996). A recent study showed that a feedback integrated in the appliances lead to up the 24% of reduction in energy consumptions (L. McCalley, 2006). The most common approach to present energy related feedback is to provide information on total energy consumption, financial cost, or environmental payback of energy produced, sometimes combined with generic advice (He, Greenberg, & Huang, 2010). In their multi-factor model of residential energy consumption, Van Raaij and Verhallen (1983) gave an essential position to the final evaluation of energy consumption, which creates a feedback loop that influences the factors that mediate the relationship between attitude and behavior. Feedback has three functions: i) it helps people to learn the consequences of their behavior in terms of energy consumption; ii) it creates and reinforces pro-environmental habits that will remain after the withdrawal of the feedback; iii) it leads to an internalization of the acquired knowledge about energy consumption. Informative feedback encourages people to experiment good and bad energy practice (Mansouri et al., 1996). An effective feedback will help consumers to be informed about energy consumption and more and confident about the efficacy of their saving behaviors. To be effective feedback should be available when is needed, that is when the action that will be described by the feedback (i.e., the consumption behavior) is produced (Stern, 1992). It is very important for the efficacy of feedback that the time interval between consumption behavior and the following information given is short (Seligman & Darley, 1976). According to

Geller et al. (1982) “ideally, feedback is given immediately after the behavior occurs”: The temporal resolution is important for feedback efficacy.

In or review of the literature we commonly came across the following types of information feedback provided by the feedback:

- *Direct feedback:* raw data about the amount of energy consumed is provided to the users (Darby, 2006).
- *Indirect feedback:* the raw data about the amount of energy consumed is processed by specific algorithms and/or integrated with different information before being presented to the users (Darby, 2006).
- *Historical feedback:* the information provided to the users is centered on the comparison between current and previous consumptions (Darby, 2006).
- *Normative feedback:* users receive information centered on the comparison between their own consumptions with the consumptions of other households. To be more effective this type of feedback should compare users with people that they perceive to be related with (Darby, 2006).
- *Disaggregated feedback:* provide separate information about the different sources of consumption (Darby, 2006).
- *Time-of-day feedback:* provide information that help people to save money postponing their consumption until off peak hours (Darby, 2006).

Wilhite and Lutzenhiser (1999) compared the effect of historical, normative and disaggregated feedback: He found that "each of these various feedback information are highly valued by costumers and in addition have effect of increasing awareness and knowledge about energy use". Feedback effectiveness can increase when feedback is given in combination with other factors such as goal setting (Ester, 1985; Locke, Shaw, Saari, & Latham, 1981), commitment (Pallak, Cook, & Sullivan, 1980) or cognitive dissonance (Kantola et al., 1984). In particular McCalley and Midden (2002) showed that feedback can be very effective when is associated with a set goal. Assigning the participants a relatively difficult goal can be more effective than the assignment of an easy goal (Becker, 1978).

1.1. Goal setting theory

It has been acknowledged in the field of psychology that feedback, or the knowledge of results, can have a positive effect on performance (Becker, 1978). This is thought to be due to the motivational effect individuals experience when they are able to see where they stand in relation to their goal. Goals and feedback are inextricably intertwined (Klein, 1991) and to optimize feedback effectiveness it is necessary to understand the relationship between goals and feedback. Feedback is the provision of information and unsolicited or unattended information can hardly be useful (Locke, 1991). In other words, if a goal to save energy does not already exist feedback should have no effect. "A goal provides a standard by which the person can judge if the feedback represents good or poor performance. To explain the effects of feedback it is necessary to know what, if any, goals or standards the person uses to appraise it" (Locke, 1991). An interpretation of this statement as it relates to energy-related feedback is that a goal to save energy can be reached more easily with appropriate feedback. In short, a goal without feedback is useless and feedback that does not match an existing goal is of little use (Becker, 1978; Erez, 1977; Ilgen, Fisher, & Taylor, 1979). Thus, in order to understand the effects of any particular feedback we must first know what the reference goal is and to evaluate the feedback itself it is necessary to understand the goal–feedback relationship.

1.2. Usability requirements

Aside for the requirement about the type of information provided, it is important that the feedback should be usable. That is, the information delivered have to be easy to understand and adopt, as well it have to support energy saving behavior. When feedback provide too much information (Ueno, Inada, Saeki, & Tsuji, 2006) or requires too much attention resources users might stop using it. The feedback have to be usable be adopted by users thus having the chance to modify their habits. There are a series of usability requirement to the provision of feedback, as schematized by Jacucci et al. (2009):

- Too much information on a large number of different appliances might induce an overload and users will drop out (Ueno et al., 2006)
- Sensors of energy consumption should not interfere with everyday family habits or leading to an additional effort to perform activities
- Information provided by feedback should be self-explanatory: elements

that are only decorative should be avoided and the information have to be presented on successive levels of detail

- Feedback should can be more effective when is easily accessible through a mobile device
- When feedback is presented should appear in a way that does not prevent any intended activity

2. Integrating concepts

The aim of BeAware project is to develop a mobile application (i.e., EnergyLife) that support and persuade people to reduce their energy consumption. Thus, the finding form the above mentioned cognitive studies were taken into account while designing the EnergyLife. The application is based as well on the key concepts in literature on studies on energy conservation and human computer interaction (Jacucci et al., 2009). The application also integrates several of the other factors evidenced by psychological studies that resulted to lead to a decrease in energy consumptions. For instances, we used feedback to sustain the awareness and context aware advices to create a cognitive dissonance between actual energy consumption and people's value. Yet actin only on the awareness might not be sufficient to achieve an actual behavioral change. The application integrated the concepts of feedback and persuasive communication present in literature, trying to make it easier – also from a cognitive point of view – to perceive consumption and above that the improper usage of appliances. Next to real time feedback and context aware advice provided to the users a cognitive support to create an association between an evident external cue and a wasting behavior. When the association is strong enough the cue will automatic activate the appropriate behavior in response to the waste of energy, without relying on an act of intention form the user (Logan, 1988).

The application was designed paying a strong attention to the guidelines of the persuasive communication theory. According to Bem (1967) people prefer to avoid non-supportive information and actively seek out supportive information. Therefore, it is likely that the generic information provided by some current energy awareness systems is not relevant to all users, and may be ignored. As stated by Costanzo et al. (Costanzo, Archer, Aronson, & Pettigrew, 1986), information should be presented in a vivid, salient and personal format. Based on these remarks, our approach is to customize the application by acknowledging the household and its articulation as the proper target as well as by using real consumption data automatically fed into the system with timely feedback reflecting the different stages of behavior change. The application is designed to accompany the user during his/her everyday usage of electricity by increasing his/her awareness and directing his/her effort in conserving energy. That is, EnergyLife was designed to comply with a series of principles derived from the literature, as reviewed by Jacucci et al. (2009):

- To provide *next-to-real-time, device-based* consumption information
- To give *advice* that directs the user's effort to improve energy conservation
- To support sustained engagement *by evolving with the users' awareness*

stage to keep the user enticed and motivated after the initial curiosity drops

- To facilitate a *shared* process of awareness building in the household through competition, discussion, and reflection inside the household

An umbrella principle to these points is that the feedback must be tailored to the users' actions and context.

3. Application rationale and interface

The application starts by displaying information about the electricity consumption in the household and in each monitored device. Several features are then added progressively: In Level 0 consumption feedback was provided. In Level 1 the users starts to receive generic advice tips. In level 2 users also receive quizzes, and smart advice tips. Finally in Level 3 an overall ranking of users and households is available, as well as a community and messaging functionality to contact other EnergyLife users. In order to advance levels, the players must achieve enough points by reading advice tips and successfully completing the quizzes.

The main interface of EnergyLife consists of a three-dimensional carousel. Each card represents an electrical appliance whose consumption is monitored by sensors and a household card represents the overall household that reports data from a sensor installed on the main meter. The fronts of the cards show the current electricity consumption of the device (or the household), and the saving achieved over the last seven days. Tapping the cards flips them around to access additional information and functionality for the given appliance, i.e., advice tips, quizzes and the consumption history for that device (or household). The application also offers a breakdown of the previous week's consumption along with the relative contribution of each device (Figure a) and an historical description of the consumption by device (Figure b).

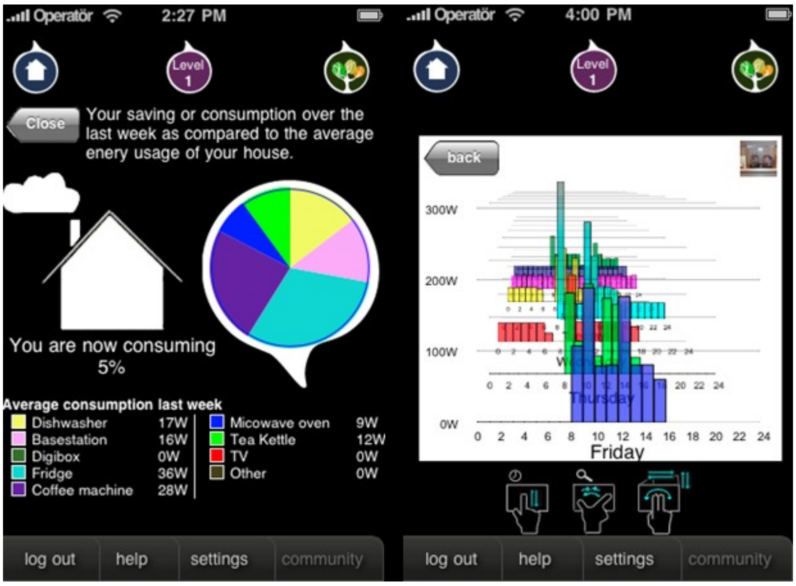


Figure . a) An example of the saving breakdown page; b) An example of the historical analysis where each row represents one day and each column represents the consumption during one hour.

The application client is a Web application adapted for touch-screen mobile devices. It was developed on HTML5, CSS3 and JavaScript and was deployed on the iPhone 3G and 3Gs. To measure the consumption of appliances in real-time, the system utilizes wireless sensors inserted in plugs. A base-station located in each household caches measurements in non-volatile memory and transfers them to the data storage in bursts.

4. Evaluation

Eight households located in urban areas in Catania (Italy) and Stockholm participated in the trials. None of the households included people working in the project. Seven sensors were installed in each house (computer, television, refrigerator, washing machine, microwave or an alternative device if not owned and two sensors connected to devices chosen by the users). Households were located in areas with high level of housing, participants owned the house where they lived. The kind of households to involve was defined considering the data on consumption and demographics, in order to identify those combining a high saving potential whit a high representativeness. The research team installed sensors and base-stations in all households and configured EnergyLife. Training in the functioning of the application was provided to all household members when the mobile phones were provided. Purpose of the trial and mutual expectations were agreed in advance, and all household members signed a general informed consent to participation. Contacts to use any time for assistance were given to users, and the proper functioning of the system was checked remotely by the research team. Data on electricity consumption were collected continuously for the three months of the trial and stored separately from the information on the users' identity in compliance with the project's confidentiality policy. The data on global household consumption was acquired through a wired pulse meter; data on consumption of specific devices was obtained through sensors placed between the specific device and the power plug. We evaluated the general effectiveness of the application trough the variation of consumption over time, and the specific effect of the smart advice tips comparing the average consumption of the devices the day before and the day after the reception of a specific smart advice. To provide a goal to participants the passage between levels was determined by their reduction of consumption and the increase of awareness score (i.e., achieved through the reading of advices and providing a correct response to the quiz). For these reason it was not feasible to examine the relationship between consumptions and the level (i.e., the type of possible interactions with the application).

5. Reduction of consumptions

To assess the impact of EnergyLife application on selected households we considered the data automatically collected by the system about electricity consumption in the trial households. Two household were excluded for technical problems that compromised the registration of the initial data of consumption. As depicted in Figure the consumption recorded in Italian and Swedish households varies during the trial period. Consumption data from Swedish households 2 and 3 show a long series of missing fata (approximated by the dotted line, ca. one month). Swedish household number 4 had a very high consumption due to an electrical heating component strongly influenced by the seasonal change in climate. Then in the analysis we did not include Swedish households 2, 3 and 4.

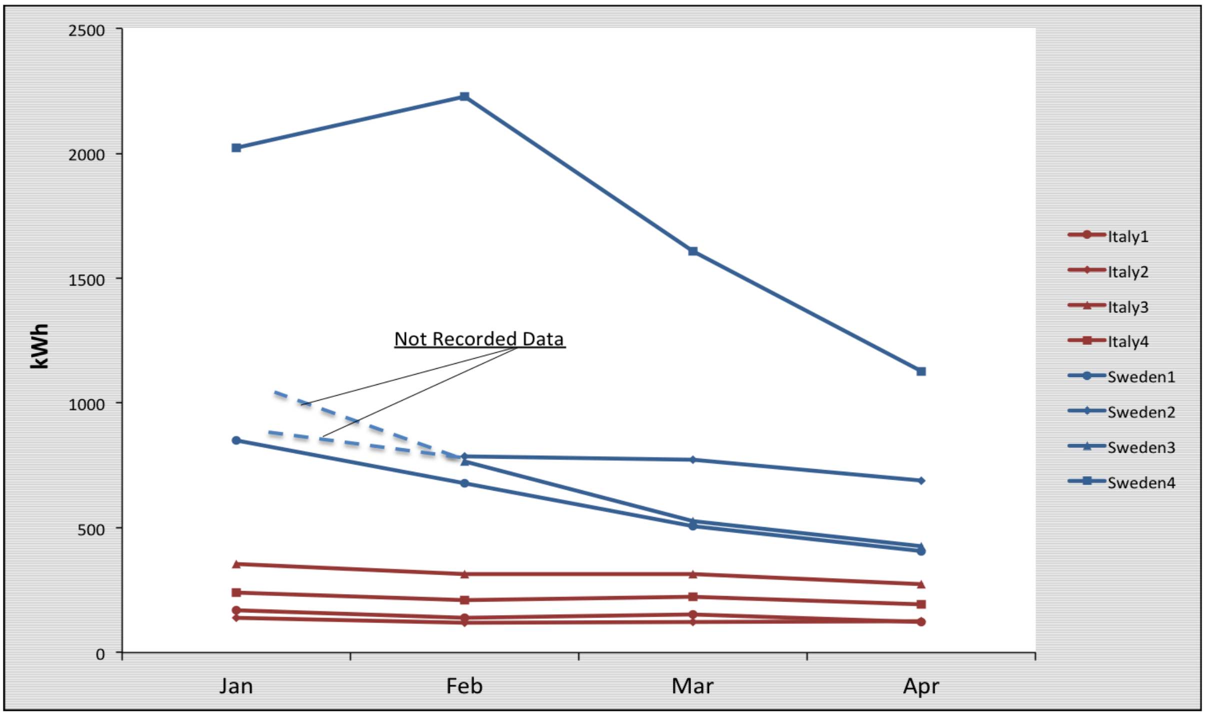


Figure . Consumption recorded in the trial households in Sweden and Italy from January to April 2011. The dotted line represents missing data.

Results suggest that making consumption more evident to people will support them n reducing their energy consumptions.

We used ARIMA (autoregressive integrated moving average) regression models to analyze the daily households consumptions (Cryer & Chan, 2008; Shumway & Stoffer, 2000). It is common for sequential data to show a high autocorrelation thus we decided to use an ARIMA regressions because allow to model the autocorrelation by adding autoregressive and moving-average terms thus the correlation of residuals does not violate the assumptions of independence. On average, households show a significant negative drift in the daily consumption, as shown in Figure $t(109) = -6.613$ $p < .001$.

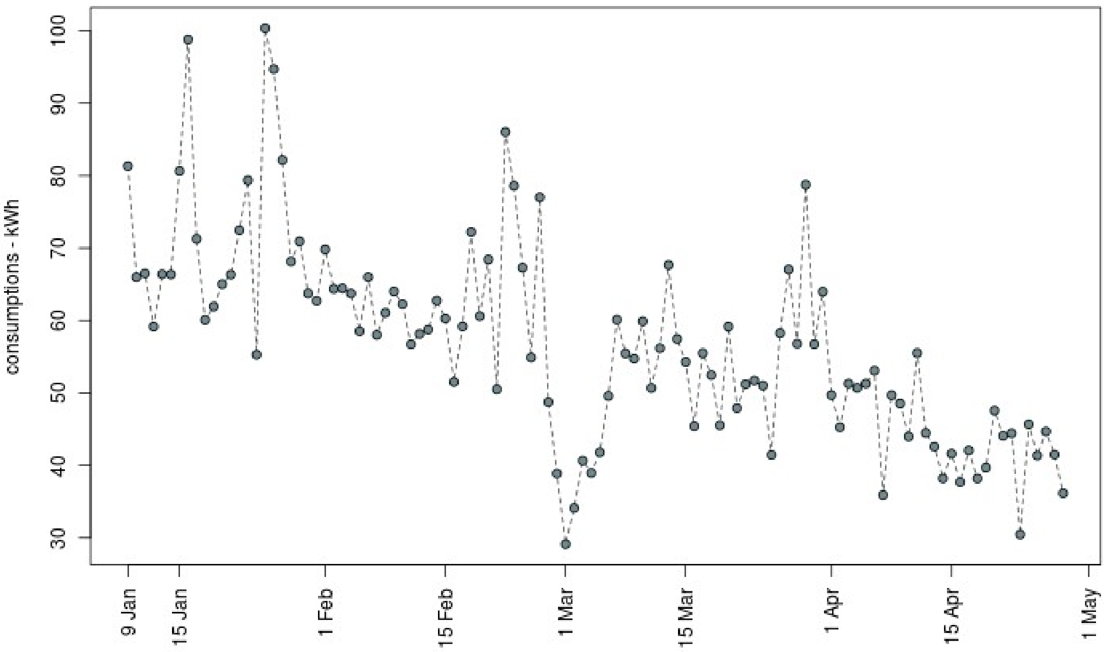


Figure . Daily households energy consumption.

The negative drift of consumptions resulted significant for all the households. In Italy1 the consumptions show a strong decrease $t(103) = -3.246$ $p = .002$ (see Figure)

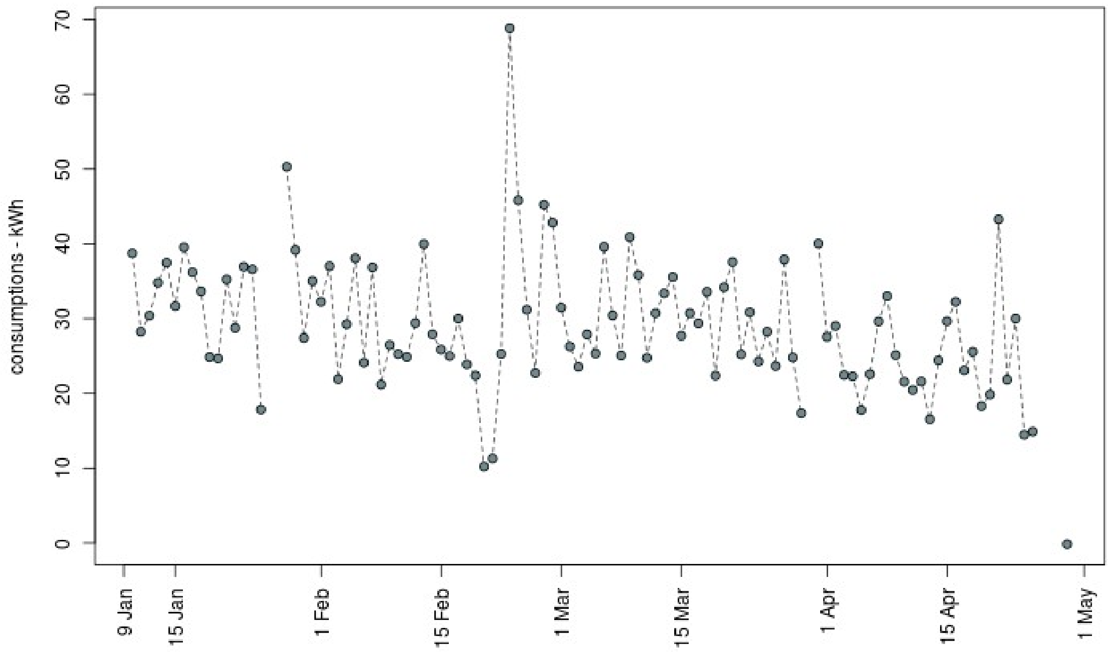


Figure . Daily energy consumption of Italy1.

As well, Italy2 show a similar negative drift of power consumptions $t(100) = -2.067$ $p = .041$ albeit the effect is less evident when plotted in the chart (see Figure).

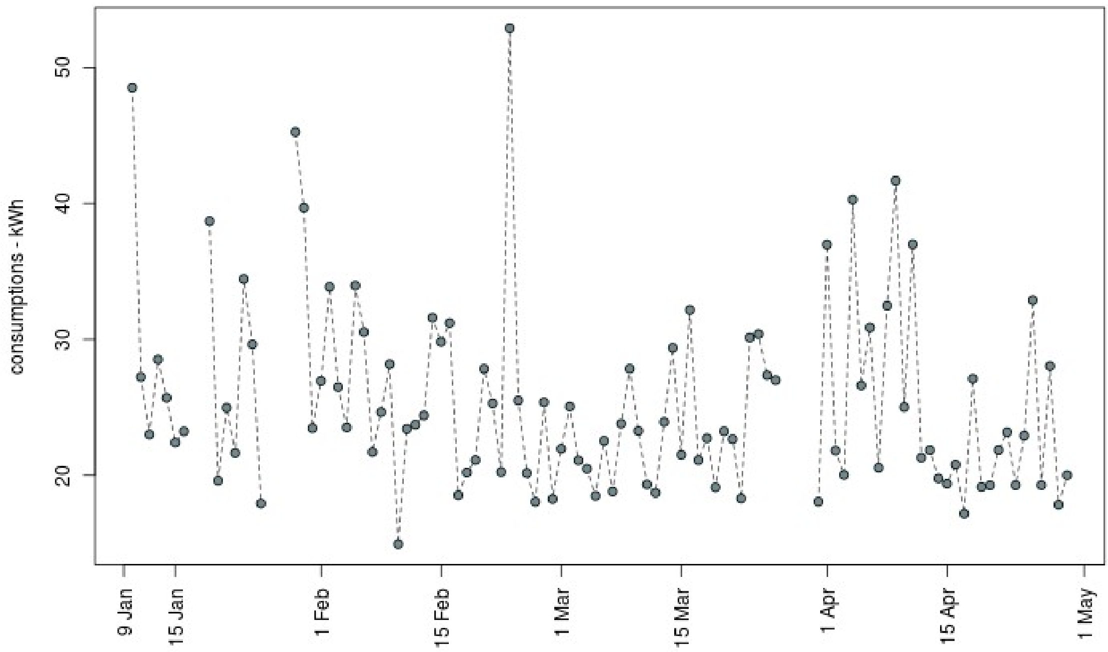


Figure . Daily energy consumption of Italy2.

Italy3 shows a negative drift in electric consumptions $t(109) = -3.91$ $p < .001$ (see Figure).

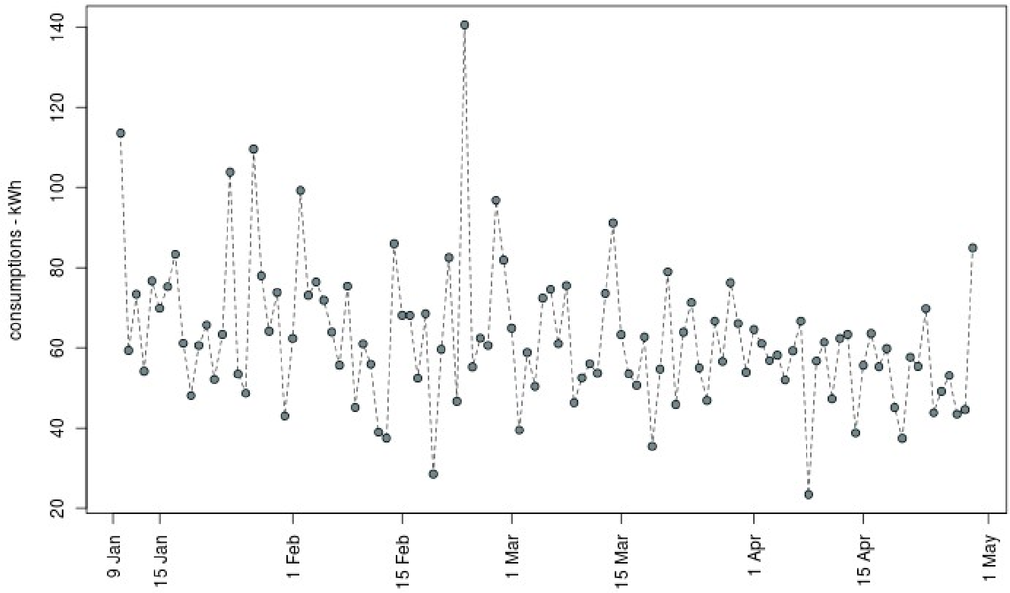


Figure . Daily energy consumption of Italy3.

Likewise, the last Italian Households (i.e, Italy4) showed a significant negative drift $t(106) = -3.532$ $p < .001$ (see Figure).

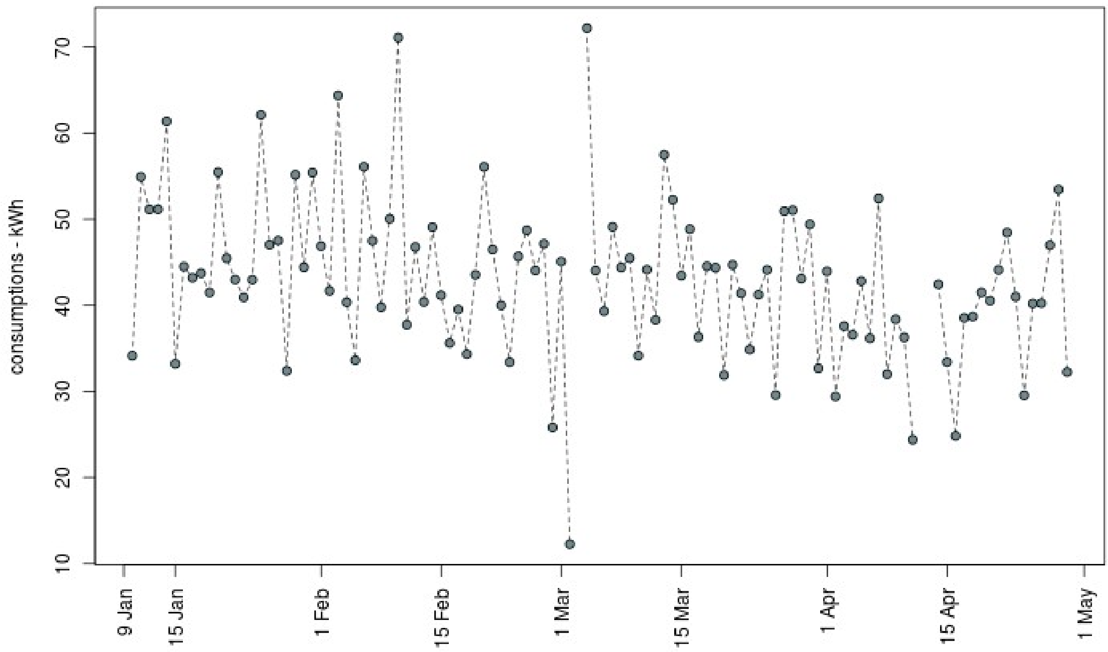


Figure . Daily energy consumption of Italy4.

The Swedish household included in the analysis seem to show the strongest response to the application (see Figure) $t(109) = -8.677$ $p < .001$.

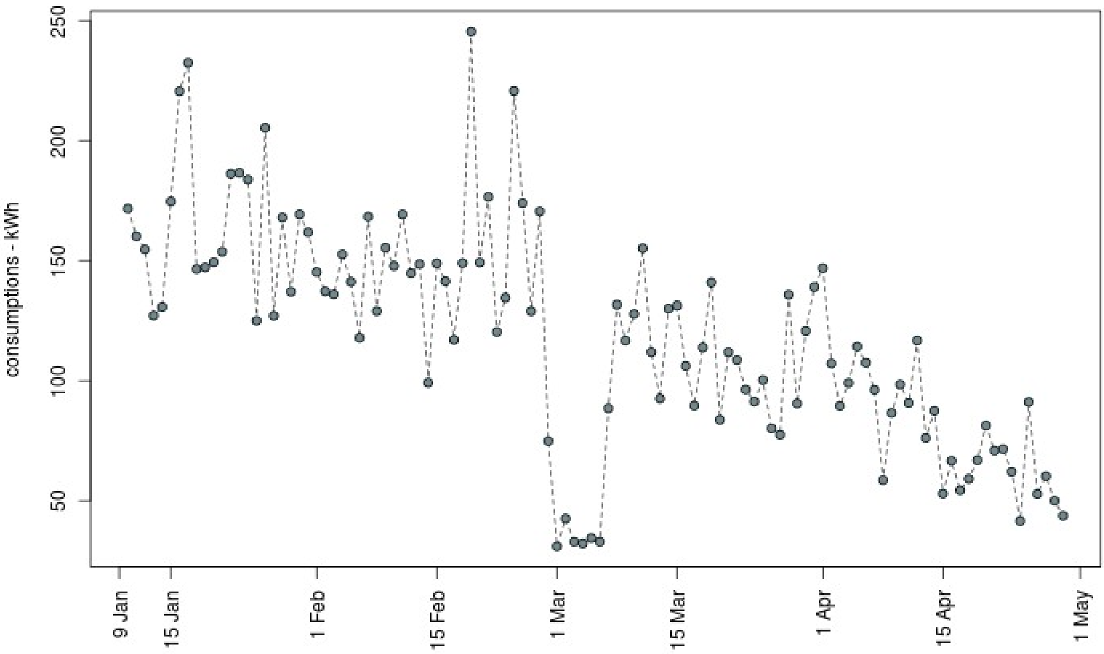


Figure . Daily energy consumption of Sweden1.

Albeit the households from south of Italy do not undergo to a strong seasonal climate change it could be argue that this decrease in consumption depended – at least in part – on the effects of variations in climate and lightening that will affect the energy consumptions, Therefore the household’s consumption during the trial period was compared to the energy consumed on the same period of the previous year. As suggested by the chart, albeit the sample size is limited there is a significant increase in the reduction of energy consumption during the trial, when consumptions are compared to the energy used in the same period of the previous year (Friedman $\chi^2(3)= 9.3$, $p = 0.03$).

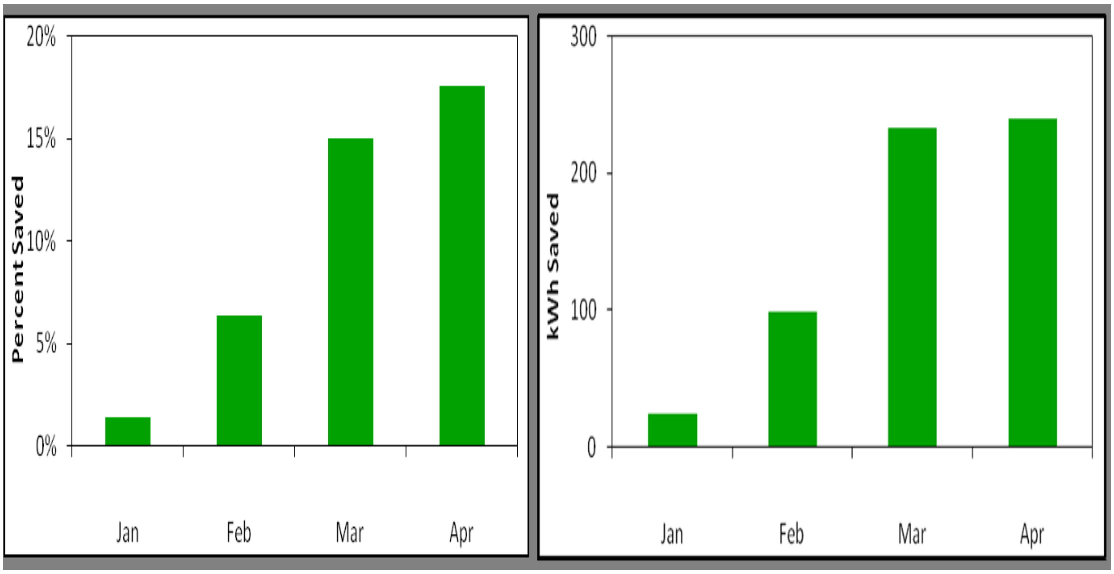


Figure . Monthly trend of the differences in energy consumption between the trial year (i.e., 2011) and the previous year (i.e., 2010).

6. Effect of the smart advice tips

Smart advice tips differ from regular advice tips in that they are triggered by the specific behavior of the user and their content incorporates information on that behavior (e.g., Device X had an on-cycle longer than 12 hours). They alert the user that the usage of a device was excessive and provide some tips on ways to remedy such overconsumption. The tips were based on information gathered from trustable sources (such as Legambiente in Italy). The actual alert was obtained by filling a template with the specific overconsumption information recorded. The final smart advice generated is different from any previous one generated from the same template since it is based on specific consumption information. One hundred smart advice templates were created, each specific for one device; thirteen of them were implemented in the trial to test the service and its effectiveness.

Each advice was designed to have one or more features referring to a specific strategy of persuasion. Advice could refer to prolonged use of stand-by mode as a user-driven waste of energy simple to identify since the consumption data (*Stand-by* feature). Other advice were set to expose the usage time of the application to demonstrate to the user the actual cumulative usage of the specific appliance (*Usage* time). The advice based on the history of the user contrasted low past and high present consumption, trying to motivate the users showing they were able to "do better than this" as in the past (*Historical*). Since power consumption is difficult to represent, we provided to the user a comparison between the power used by an appliance and the CO_2 released to produce it, often in association with the number of trees required to compensate that (*CO_2*). To provide a gradation in the advice some advice used a friendly language (*Friendly*) whereas others were more exhortative to saving. There was an average number of 2 features per advice (range 1-4).

Table : Features of the smart advice templates.

Feature	Advice	Created	Sent
Stand-by	The computer that you left in stand-by for ?? hours, made you consume ?? kWh this week. Please remember to turn it off completely, to avoid wasting electricity	4	37
Usage time	The day ?? you used the washing machine ?? hours longer than usual. Please try to use it only at full load	7	353
Historical	This week your fridge spent ?? kWh more than last week. To save electricity reduce the duration of door openings and do not insert food when it is still warm	5	182
CO_2	This week ?? trees had to absorb the CO2 produced by your PC. Help the environment by changing the energy saving setting of your PC	5	114
Friendly	This week the micro wave oven spent ?? kWh more than last week. Please try to use it as little as possible to save electricity	6	205

The trigger conditions for generating smart advice were different for each device and focused on the prolonged use of stand-by mode (e.g., "The computer that you left in stand-by for ?? hours, made you consume ?? kWh this week. Please remember to turn it off completely, to avoid wasting electricity"), a high cumulative usage over a certain period of time varying according to the device (e.g., "The day ?? you used the washing machine ?? hours longer than usual. Please try to use it only at full load"), or an increase compared with past consumption (e.g., "This week your fridge spent ?? kWh more than last week. To save electricity reduce the duration of door openings and do not insert food when it is still warm)". An on-cycle was defined using the following algorithm: (i) On-cycle starts when the recorded power has been above a cutoff point of 0.1W for at least 3 consecutive measurements; (ii) On-cycle ends when the recorded power has been below a cutoff point of 0.1W for at least 3 consecutive measurements. Standby mode was detected via the following algorithm: (i) Detect and identify all stable power states of the device; (ii) If there are more than 2 stable states and at least 1 of them consumes less than 10W, designate the lowest one as stand-by mode. As the stand-by detection algorithm might fail for devices with particular consumption patterns, its accuracy was confirmed by a human expert for each device. The household consumption was compared to all of the triggering criteria once a day. If there was a match, the related smart advice was generated (or more than one, if more criteria were met). A smart advice was sent when the associated device activated one of the following triggers:

- Consumption during the 2 last calendar week was higher that the consumption during the previous 2 week by 5%
- Consumption during the last 7 days was higher that the consumption during the previous 7 days by 5%
- Device had an on-cycle longer than 12 hours
- Device had an on-cycle longer than 5 hours during nighttime
- Over last week the device was turned on for more than 84 cumulative hours
- Device had a stand-by cycle longer than 5 hours

- Device was in stand-by mode for more than 35 cumulative hours over last week

To examine their effectiveness we compared the consumption of each device the day before and the day after a participant in the household read a specific smart advice tip. In this analysis we used a linear mixed model that considers both households and devices as “units” randomly sampled for the population of existing households and devices, like participants in a repeated measure ANOVA. We included the trial day as a covariate in the model to calculate the effect of the smart advice over and above the global reduction of consumption through monitoring and the other non-specific features of Energy Life. The results show a significant reduction in the electricity consumption of a device following the presentation of smart advice ($\chi2(1)=6.75$ $p < 0.01$), amounting to 38% of the average consumption of the relative device the day after the delivery of a smart advice (Figure X).

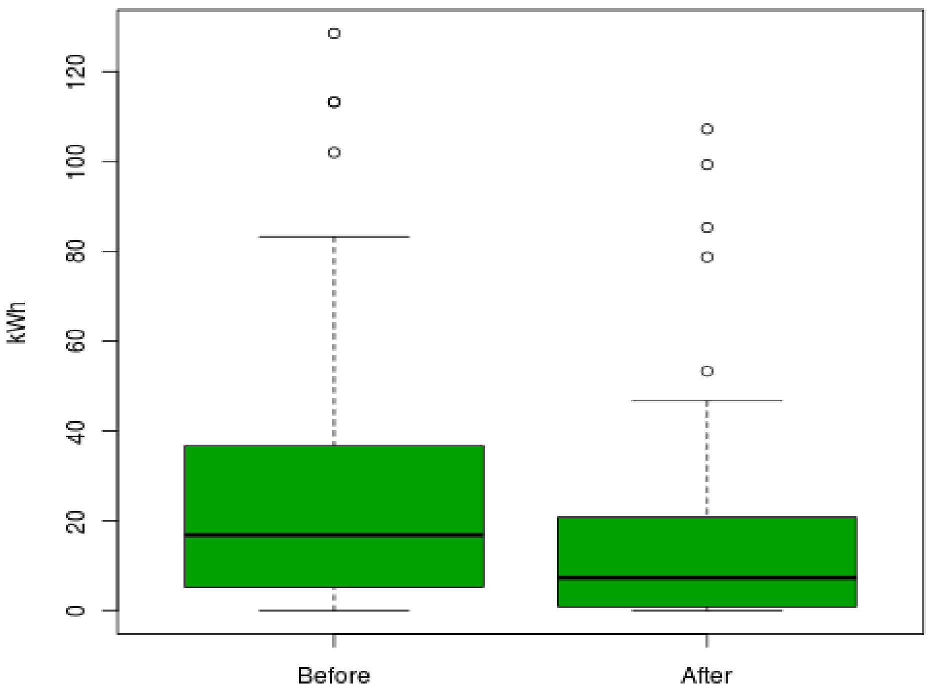
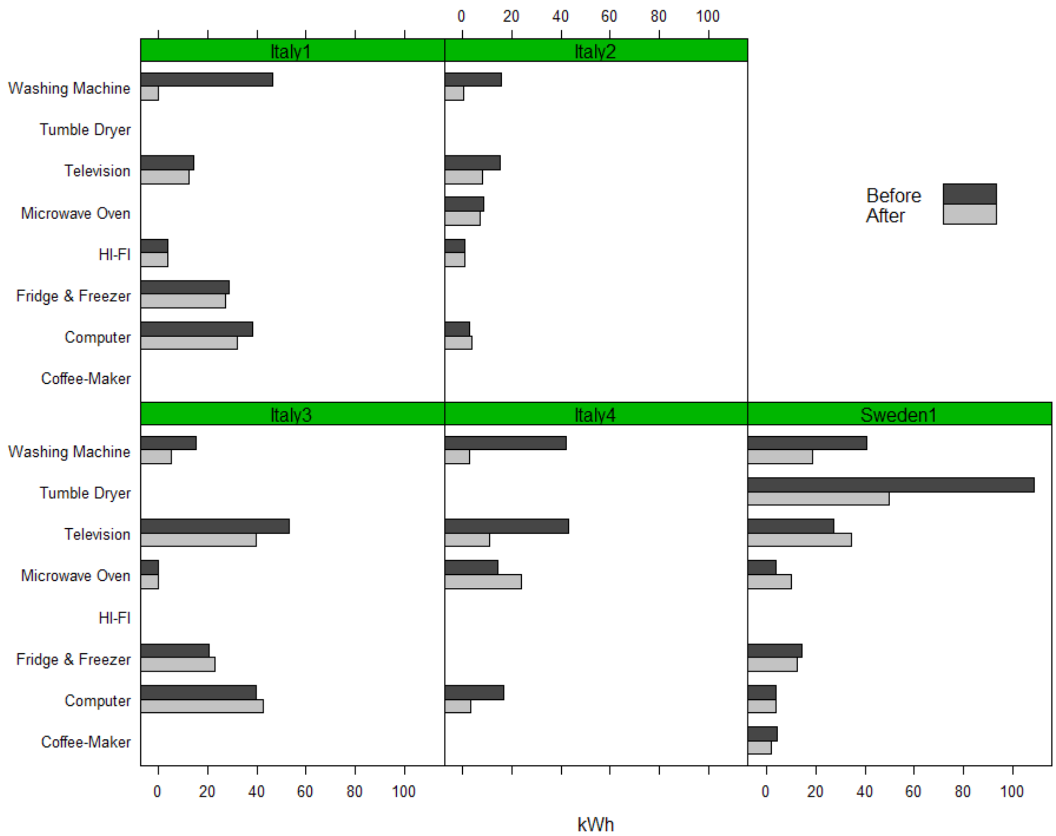


Figure . Box plots of electricity consumptions the day before (left) and after (right) the receptions of a smart advice tip. Isolated dots represent outlier observations.

Energy life though smart advice tips introduced two important innovations. Smart advice tips were triggered by specific events and therefore provided a situated feedback. That showed it is possible to create advice specific for a situation, and through real time processing to provide an immediate tip contextual to the present action. Also, smart advice tips were designed to be able to identify wasting behaviors, such as device in stand-by mode for a prolonged time and long continuous usage of appliance in an unexpected time (e.g., the television was on for all the night) suggesting to the users that they forgot to switch off the appliance. That make possible to specifically target wasting behaviors separating them form large but necessary consumption of energy. That will allow motivating the users to be efficient by adapting the message to consumption and waste context, and create a stronger connection between the user's action and the feedback. In fact, result showed that this strategy proved effective in reducing consumption over and above the unspecific effect of the application.



8. General discussion

Overall, results suggest that considering the cognitive functions that supports the implementation of energy saving routines in daily life can improve our understanding of pro-environmental behaviors. In the literature review of we encountered a large number of studies that have explored the role of psychological factors in energy saving and pro-environmental behaviors. Other studies introduced alternative models specific to the environmental topic: the new environmental paradigm and the value belief norm theory (Steg et al., 2006; Stern, 2000). The theory of planned behavior (Ajzen, 1991) and the norm activation model (Schwartz, 1977) provided the theoretical foundation to a great number of the studies exploring pro-environmental behaviors. The theory of planned behavior predicts the engagement on pro-environmental behaviors on the base of the weighting of costs and benefits (i.e., financial, social, effort, etc.). Personal norms model view pro-environmental behaviors as the result of a decision to engage in an altruistic pro-social behavior that overcomes the personal interests. Social norm and social identity theories described the effect of the social pressure – respectively in terms of prescription or identification with the reference group – on the engagement on energy pro-environmental behaviors (Schultz et al., 2007; Siero et al., 1996).

Several other factors, mainly derived from social psychology, have been shown to affect people's engagement on pro-environmental and energy saving behaviors. Environmental values are typically developed following important experiences (such as direct experiences of environmental degradation) and under the influence of important figures and the close social environment (Chawla, 1999). Then environmental values can affect pro-environmental (Kollmuss & Agyeman, 2002). When a pro-environmental motivation is in contrast with a non-environmental motive the stronger will usually win. Emotional involvement in environmental issues (i.e., the strength of the affective relationship) plays an important role in determining our values and attitudes towards this issue (Chawla, 1999). In turns, emotional involvement requires environmental knowledge to direct an action in an appropriate form (Fliegenschnee & Schelakovsky, 1998; Preuss, 1991). Moreover some type of emotional reaction, such as fear, are more likely to trigger a compensatory pro-environmental behavior than others, such as guilt (Kollmuss & Agyeman, 2002). The exposition of the cognitive dissonance between saving intentions-values and wasting behaviors can drive people to reduce their energy consumptions (Kantola et al., 1984). On the other hand this dissonance potentially can be resolved turning aside the pro-environmental values, leading to a disinvestment. Locus of control plays an important role in determining the effort invested in pro-environmental behaviors. Even when supported by a strong motivation, people with an external locus of control are much less likely to engage in pro-environmental behaviors because they consider their action do not contribute to a significant change in the course of the events (Hines et al., 1987). Environmental knowledge does not show a strong association with the engagement in pro-environmental behaviors. Yet there are a number of misconceptions on the details of energy consumption, such as how much energy is used by which devices (see Steg, 2008, for a review). Environmental awareness refers to the knowledge about the impact of human behaviors on the environment (Kollmuss & Agyeman, 2002). The development of a strong environmental awareness is commonly constrained by three cognitive barriers (Preuss, 1991): i) direct experiences of environmental degradation are rare; ii) the gradual nature of environmental degradation; iii) the complexity of the mechanisms at the base of environmental degradation. Cognitive constraint might filter information that will be linked to our intellectual understanding but not to our emotional experience.

The studies we have described so far explored the mechanisms and the factors that lead people to a *decision* to engage in pro-environmental or energy saving behaviors. However, why some decision turns into an actual behavior while others are not applied? In fact, whereas the concern to environmental issue is generally high people often do not act in line with their concerns (Steg, 2008). Several studies explored the factors that mediate the realization of a behavior. Several pro-environmental behaviors require adequate services and infrastructures to be implemented, and an inefficient infrastructure often increase the effort required (Kollmuss & Agyeman, 2002). Personal norm that prompt altruistic behaviors are activated by situational cues or by the experience of the others (Biel & Thøgersen, 2007). Three main factor mediates the relationship between attention and behavior. Temporal stability of intention (i.e., the absolute change over time of the measured any individual intention) is an obvious requirement for the influence of an intention on behaviror. Pereceived behavioral control, the beliefs over the personal ability to execute an action, has been shown to influence both the state of the intentions and the production of the behaviors (Richetin et al., 2011) Implementation intentions are action plans based on the construction of an association between anticipated situation and planned response (Gollwitzer, 1993, 1999). The formation of implementation intentions transfer the control over the production of behaviors to the cues provided by the situation. In fact, when people are prompt to the construction of implementation intentions the gap between intention and behavior is reduced.

Recent studies have shown that the realization of intention can be mediated by the efficiency of the cognitive functions that support the intended behavior. The executive functions and ability to inhibit the responses have been shown to moderate the intention behavior relationship for physical activity and dietary behavior (Allan et al., 2011; Hall et al., 2008). We hypothesized that a number of saving behaviors can stress the underlying cognitive processes, thus cognitive efficiency can moderate the intention behavior relationship. In particular, cognitive lapses can be one of the reasons behind energy wasting behaviors.

For the first experiment we made a distinction between energy saving behavior whom stress or not the supporting cognitive functions (i.e., mainly functions involved in action and performance control). All participants to the experiment reported to be very involved or involved in energy conservation. The distinction between the two classes of behaviors was made “a-priori” trough a cognitive analysis of both the actions and the circumstances in which the action take places. Results showed that working memory, speed of processing and sustained attention (measured through the PASAT; Stablum et al., 2007) predict the engagement in energy saving behaviors that stress the cognitive system. In the second experiment, we examined the role of working memory, speed of processing and sustained attention on a directly observed saving behavior. To study that following the administration of the PASAT we created the opportunity for the production of a saving behavior (i.e., turning off the light when leaving the laboratory). In this case, the accuracy on the PASAT was not a significant predictor of the saving behavior, albeit people turning off the light were on average more accurate than people leaving it on. Participant's report during the informal post experimental debriefing suggested that while some participants just forget to turn off the lights other decided to leave it on. This explanation was consistent with the qualitative evaluation of the distribution of the PASAT score in in the two group (i.e., participant that turned the light off or not), and the result form a cluster analysis conducted over the accuracy on the PASAT and the production of the saving behavior. These considerations were taken into account in the design of the third experiment. To achieve a greater sensitivity we created the opportunity for four different saving behaviors, and we ensured that the participants felt authorized to turn off the devices asking the participants to turn them on at the beginning of the experimental session. In this experiment, we examined the effect of central executive load (Baddeley, 1986), induced trough a dual task paradigm, on the production of energy saving behaviors. Result showed that the central executive load decreases the engagement in energy saving behaviors. The effect seems specific for the saving behaviors (and perhaps contexts) that are not connected with an evident environmental stimuli or cue. When the saving behavior is associated with an external cue it might be triggered automatically with no need of an act of intention (Logan, 1988). Overall, our results suggest that reduction of the cognitive load (or cognitive training of underlying functions) can help people to reduce their consumptions.

The psychological theories and factors encountered in literature were then integrated with usability principles in a feedback base application. The application should as well reduce the cognitive resources required to perceive energy consumption and waste, and ideally help to automatize saving behaviors associating them to external cues. Feedback is a self-teaching tool that allows users to learn directly from their experience and was experiment the consequences of their behaviors in terms of consumption (Darby, 2006). The application was designed to provide a next to-real time feedback, to allow users to associate their behavior to its consumption without having to recall and manipulate information in their episodic memory. In fact, feedback is more effective when it is provided at the same time of the action (Geller et al., 1982). As feedback is more effective when is supported by a goal (Klein, 1991), the application included a community level to provide a climax of cooperative competition. Moreover, advice tips (generic and smart) were included to add a helpful and supporting "voice" to the application.

Result of the analysis over energy consumption showed a decrease of energy use over time for all the families in the trial. Moreover, the household show a progressive reduction of consumption respect to the energy used in the same period of the previous year. Overall, an application designed according the above mentioned principles seem successful in the reduction of energy consumption. When a member of the household received a smart advice specific to an appliance, the consumption of that appliance was then decreased. The effect resulted significant over and above the generic effect of the application on energy consumptions.

Overall, our results suggest that our understanding of energy conservation behaviors might be improved by considering the influence of cognitive mechanisms underlying their execution. 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. A cognitive model supporting a more effective intervention would have major financial and environmental benefits. In fact, the field trial of EnergyLife application shows that when consumptions are made more evident people tend to decrease their use of energy. Still the field trial with EnergyLife was unspecific, integrating persuasive features such as feedback, community ranking, etc. Further interventional studies isolating the effect on specific cognitive functions are required. Future intervention should facilitate the implementation of saving routines reducing the required cognitive involvement.

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