Physical Activity in Older Adults: The Role of Intentions, Executive Control Resources and Implementation Intentions

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Objective: The purpose of this investigation was to examine the effect of implementation intentions on physical activity in older adults with stronger and weaker executive control resources (ECRs).

Methods: One hundred and ten community dwelling older adults (Mage=74.42) were randomly assigned to receive either a physical activity implementation intention intervention, a control intervention, or no-treatment. Three ECR facets (inhibition, task-switching, working memory), baseline behaviour and baseline intentions were assessed during the initial laboratory session. During 4 weekly follow-up telephone interviews, participants reported physical activity behaviour for the previous week, and refreshed implementation intentions for each upcoming week.

Results: A main effect of treatment condition on 1-month self-reported physical activity was observed, with those in the experimental group reporting significantly higher physical activity than those in the control or no-treatment conditions. In addition, a significant 2-way (intention strength by treatment condition) interaction emerged, with the experimental group showing higher intention-behaviour correspondence than the control and no-treatment groups. A marginal 2-way interaction of intention and behavioural inhibition was also detected; those with stronger behavioural inhibition had higher intention-behaviour correspondence relative to those with weaker behavioural inhibition across all three treatment conditions.

Conclusions: Implementation intentions are effective in facilitating physical activity in healthy older adults. The findings also indicate that behavioural inhibition may be important for the

moderation of intention-behaviour relationships in the context of physical activity, regardless of goal setting strategy.

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List of Abbreviations

ECR Executive Control Resource

GNG Go/No-Go Reaction Time Task

KT Keep Track Task

NL Number-Letter Task

TPB Theory of Planned Behaviour

TRA Theory of Reasoned Action

1.0 Introduction

Despite the many benefits of regular physical activity (Warburton, Nicol, & Bredin, 2006), many people are insufficiently active (Statistics Canada, 2011). Even when holding intentions to engage in physical activity, people often do not adequately act on their goals (Godin & Connor, 2008). While theories of behaviour that highlight intentions as a proximal predictor of behaviour are widespread in health behaviour literature (Sheeran, Milne, Webb, & Gollwitzer, 2005), intentions are found to be moderate predictors of behaviour. As such, a large proportion of individual health behaviour remains to be explained (Sheeran, 2002).

Recent evidence has revealed the role that biologically determined self-regulatory abilities known as executive control resources (ECRs) may play in intention-behaviour relationships in the context of health behaviour (Hall, Fong, Epp, & Elias, 2008b). Specifically, ECR function was found to be related to the correspondence between intentions and behaviour for physical activity and dietary goals; those with stronger ECRs exhibited greater intention-behaviour correspondence compared to those with weaker ECRs. These findings suggest a moderating role of ECRs on the intention-behaviour relationship.

Although there is a growing literature examining the extent that individuals can directly strengthen ECRs through cognitive training, such training is often intensive and time consuming (Basak, Boot, Voss, & Kramer, 2008; Dahlin, Nyberg, & Backman, 2008), with questionable efficacy (Owen et al., 2010). Alternatively, strategies that compensate for low ECR may be of greater relevance when examining methods to increase intention-behaviour relationships (Hall, Zehr, Ng, & Zanna, 2011). These brief goal-setting plans—implementation intentions

(Gollwitzer, 1993)—have been shown to increase intention-behaviour continuity in a variety of health behaviour contexts (for a review, see Sheeran et al., 2005).

Implementation intentions may be particularly applicable for facilitating health-protective behaviour in older adults. Considering age-related changes in cognitive ability (Brayne, Gill, Paykel, Huppert, & O'Connor, 1995; Lindenberger & Baltes, 1997; Maylor, 1993; McIntyre & Craik, 1987; Potter, & Madeleine, 2008; Salthouse, 1996; Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000), implementation intentions may provide greater intention-behaviour correspondence in older adults when holding intentions to engage in health-protective behaviour.

The current investigation will examine the effect of an implementation intention intervention for increasing physical activity levels in older adults. Moreover, the extent that implementation intentions increase intention-behaviour correspondance will be assessed. The moderating role of ECRs on intention-behaviour relationships will also be examined. Finally, the extent that implementation intentions facilitate physical activity in those with strong and weak ECRs will be assessed.

2.0 Literature Review

2.1 Intentions and Behaviour

Psychological models of individual health behaviour often emphasize the intuitive notion that behavioural intentions will predict subsequent behaviour. Two prominent theories of behaviour, the theory of reasoned action (TRA; Fishbein & Ajzen, 1975) and its later amended version, the theory of planned behaviour (TPB: Ajzen, 1991) have at their crux, the contention that intentions are the "…immediate determinants of the corresponding behaviours" (Fishbein & Ajzen, 1975). This link between intention and behaviour is well documented with one meta-analysis estimating that intentions account for 28% of the variation in individual behaviour (Sheeran, 2002).

However, despite the success of intentions as a significant predictor of behaviour, the majority of the variability in behaviour remains undetermined (Godin & Connor, 2008; Sheeran, 2002). Moreover, the proportion of variance in behaviour predictable from intentions is reduced when only experimental studies are considered. In a meta-analytic review of the literature examining the link between intentions and health behaviour, Webb and Sheeran (2006) reported that a medium-to-large change in intention was required to elicit a change in behaviour that was only small-to-medium. The authors noted that intentions were even less predictive of behaviour when controllability of the behaviour (perceived or actual) was lower. As such, factors that affect the extent to which individuals possess volitional control over health-protective behaviour must be more fully considered when examining the intention-behaviour relationship.

Temporal dimensionality has been highlighted as being important for the volitional control of health behaviour (Hall & Fong, 2003; 2007). Although health-protective behaviours provide health benefits in the future, they are often associated with immediate contingencies that can derail successful behavioural performance irrespective of health behavioural intentions. For example, in the context of physical activity goal attainment, it is not difficult to think of immediate contingencies that may be related to inconvenience or discomfort ("I'd rather relax after work than go to the gym"; "I feel too tired to exercise"; "I don't have time"). As Hall and Fong (2007) point out, these immediate contingencies are likely more salient at the time of behavioural performance compared to the distal benefits of such behaviour. Given that these immediate barriers to successful health goal achievement exist, a more nuanced perspective of how intentions predict behaviour must be considered.

One potential moderator of the intention-behaviour link is the presence of biologically based executive control resources (ECRs) associated with the operation of the prefrontal cortex; more intact ECRs may facilitate self-regulatory success by enhancing the extent to which intentions can be translated into actual behaviour (Hall & Fong, 2007;Hall, Elias, Fong, Harrison, Borowsky, & Sarty, 2008a; Hall et al., 2008b).

2.2 Executive Control Resources

ECRs have been conceptualized as a group of cognitive processes that facilitate top-down control of behaviour (Miller & Cohen, 2001). As opposed to more routine and automatic behaviours that require little attention, ECRs guide behaviour in situations that require deliberate or effortful behavioural control (Miller & Cohen, 2001). As such, ECRs have been traditionally thought to be chiefly involved with the performance of goal-oriented behaviour (Banich, 2009; Miller, 2000).

As a construct with considerable multidimensionality, ECRs encompass a myriad of functions including "…prioritizing and sequencing behaviour, inhibiting familiar or stereotyped behaviours, creating and maintaining an idea of what task or information is most relevant for current purposes,…providing resistance to information that is distracting or task irrelevant, switching between task goals, utilizing relevant information in support of decision making, categorizing or otherwise abstracting common elements across items, and handling novel information or situations" (Banich, 2009). However, through the use of latent variable analysis, Miyake, Friedman, Emerson, Witzki, and Howerter (2000) argued that ECRs could be reduced to three interrelated (but separable) categories of process: the ability to switch between different tasks ("switching"), updating and monitoring working memory ("working memory"), and the inhibition of prepotent or competing responses ("inhibition"). The latter component has been identified by Hall & Fong (2007) as being particularly important for self-regulation of health behaviour, which commonly requires suspending "default" unhealthy behaviours in order to make room for healthier alternatives. As such, it is important to consider the putative biological correlates of executive function.

2.3 Biological Basis of Executive Control Resources

ECRs are thought to arise from a cortical system with important nodes residing in the prefrontal cortex (Miller, 1999; Miller & Cohen, 2001; Stuss & Benson, 1984). This hypothesis is supported by the evidence that individuals with prefrontal lobe damage often demonstrate difficulty performing tasks that require effortful cognitive control (Bechara, Damasio, Tranel, & Damasio, 1997; Bechara, Tranel, Damasio, & Damasio; Glosser & Goodglass, 1990). Additionally, prefrontal cortex activity has been shown to be correlated with tasks that require response inhibition (Liddle, Kiehl, & Smith, 2001; Sasaki, Gemba, Nambu, & Matsuaki, 1993), task switching (Konishi et al., 1998), and working memory processes that work to manipulate stored information (Smith and Jonides, 1999).

Specific regions of the prefrontal cortex have been linked to the operation of particular cognitive processes. The dorsolaterprefrontal cortex region has been primarily implicated in the elicitation of attentional processes that play a role in the top-down selection of task-relevant representations and the subsequent activation of brain structures necessary to fulfill a particular objective (Banich et al., 2000; Banich, 2009; Johnston & Everling, 2006). The ventromedial and orbitofrontal regions of the prefrontal cortex are associated with decision-making, emotional regulation, and inhibitory processes (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003; Bechara et al., 1997; Bechara, Tranel, Damasio, & Damasio, 1996; Fellows & Farah, 2007; Dillon & Pizzagalli, 2007; Zald, Mattson, Pardo, 2002).

Other proximal structures such as the anterior cingulate cortex have strong structural connections with the prefrontal cortex (Barbas & Pandya, 1998) and often exhibit co-activation with the prefrontal cortex (Paus, Petrides, Evans, Meyer, 1993). Also highlighting other links to the motor regions (Luppino, Matelli, Camarda, Gallese, & Rizzolatti, 1991), Paus (2001) argues that the anterior cingulate cortex is well-suited for involvement in behavioural control. As opposed to implementing and maintaining a task-relevant attentional set as is observed with the dorsolateral prefrontal cortex, it is suggested that the anterior cingulate cortex plays a supportive evaluative role such that it monitors and informs the dorsolateral prefrontal cortex of competing responses or errors (Banich, 2009; Carter, Braver, Barch, Botvinick, Noll, & Cohen, 1998; MacDonald III, Cohen, Stenger, & Carter, 2000). Consequently, if an error in response selection is detected, the anterior cingulate cortex indicates to the dorsolateral prefrontal cortex that more rigorous top-down control of task-relevant representations is required (Banich, 2009).

2.4 Executive Control Resources and Self-Regulation

When considering the cognitive and behavioural control functions hallmark to prefrontal functions, it becomes apparent that ECRs have significant relevance to prevailing models of self-regulation. Carver and Scheier's (1982) Control Theory of self-regulation, heavily based on the notion of a negative-feedback system that monitors and subsequently aligns behaviour with goal objectives, is highly analogous to the task-directed and decision-making processes of the prefrontal cortex and the evaluative function of the anterior cingulate cortex.

ECRs may also have relevance to Baumeister's ego depletion model (Baumeister, 1998; 2002; Baumeister, Bratslavsky, Muraven, & Tice 1998). The central tenet of this model is that self-regulatory control is a diminishable resource that can be exhausted through effortful behavioural regulation. Past research has demonstrated that individuals who were required to effortfully regulate behavior in one task performed more poorly on a subsequent cognitive task compared to individuals who were not obliged to regulate behavior (Baumeister et al., 1998). This notion of self-control as a limited resource may have some physiological basis. In their review, Gailliot and Baumeister (2007) contend that the depletion of self-control resources may be as a result of a corresponding reduction in blood-glucose. They go onto to note that studies that examined tasks that draw on prefrontal function showed that performance was associated with blood-glucose levels (Blackman, Towle, Lewis, Spire, & Polonsky, 1990; Donohoe & Benton, 1999). However, currently the idea of "negative transfer" (i.e., the notion that performing one cognitive task reduces performance on others) is not well-supported in general (Brewer, Spillers, McMillan & Unsworth, 2011), and many are beginning to question the validity of the limited resource model of self-regulation. For example, Job, Dweck and Walton (2011) demonstrated that self-regulatory fatigue effects arise only among those participants who already believe that such effects exist, and numerous failures to replicate even the most basic of the self-regulatory fatigue effects have been reported (e.g., Holmqvist, 2008).

Whereas prior models explained self-regulation exclusively in terms of social cognitive processes, longstanding knowledge of prefrontal function provides a biological underpinning for such processes. Consequently, more recent models of health behaviour explicitly acknowledge the importance of biologically determined ECRs in self-regulation. For instance, Hall and Fong's (2007) Temporal Self-Regulation Theory specifically points to the contribution that the prefrontal cortex and the anterior cingulate cortex may play in behavioural regulation in the context of health behaviour. The authors postulate that "…subtle naturally occurring differences in brain function between and within individuals should be associated with health behaviour patterns" (Hall & Fong, 2007), pointing to the necessity of inhibiting prepotent responses in the service of health goals. They suggest that the behaviour of those exhibiting weaker ECRs may be influenced more strongly by immediate or prepotent cues in the environment relative to those with stronger ECRs. As such, the theory asserts that individual differences in ECRs may play an important moderating role in the relationship between intentions and behaviour given that successful goal attainment often involves effortful regulation of behaviour.

To date, several studies have linked stronger ECRs with healthier dietary behaviours, reduced substance use, and better physical activity adherence (Hall et al., 2008a; Hall, 2011; Hall, Elias, & Crossley, 2006; McAuley et al., 2011). In one study, using fMRI imaging techniques, it was found that those who had greater engagement of the anterior cingulate cortex when completing a Stroop task, demonstrated greater concordance between their intentions to engage in physical activity and behaviour implicating the role of brain-determined self-regulatory ability in successful behavioural performance.

Research has also demonstrated the engagement of frontal lobe structures when considering choices that involve deciding between immediate and delayed rewards (McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007; McClure, Laibson, Lowenstein, & Cohen, 2004). Given that performing many health-protective behaviours, in essence, involve choosing a later health-protective 'reward' over an immediate reward, these findings further support the self-regulatory role of ECRs in the context of health behaviour.

2.5 Executive Control Resources and Age

When considering the potential importance of ECRs in relation to health behaviour, relative deficits in ECR ought to be regarded as a possible detriment to successful health behaviour performance. In this context, populations with widespread deficits in cognition related to self-regulatory ability may be at a disadvantage when striving to implement health behaviour goals. Advanced age is often accompanied by a broad decline in cognition affecting diverse cognitive processes (Brayne, et al., 1995; Lindenberger & Baltes, 1997; Maylor, 1993; McIntyre & Craik, 1987; Salthouse, 1996; Potter & Grealy, 2008; Wecker, et al., 2000). ECRs are particularly affected by older age, with reductions in volume observed in the prefrontal cortex (Raz, Briggs, Marks, & Acker, 1999; Raz, Gunnin-Dixon, Head, Dupuis, & Acker, 1998) as well as an accelerated decline in ECRs after the age of 60 in healthy adults (Treitz, Heyder, & Daum, 2007). This age-related decline in ECRs may have important implications in regards to health behaviour. Indeed, if older adults experience a relative deficit in self-regulatory ability, greater difficulty in achieving health-protective behaviour may be experienced.

2.6 Improving Self-Regulation

There has been a burgeoning literature exploring ways in which to improve self-regulatory ability. Research has examined the extent that ECRs can specifically be boosted through brain training exercises (Basak, Boot, Voss, & Kramer, 2008; Dahlin, Nyberg, & Backman, 2008). However, such exercises can be time-consuming with one investigation reporting benefits after 23.5 hours of training (Basak et al., 2008). More importantly, recent findings suggest that improvements in performance on brain training exercises may not translate into improvements in cognition relevant to day-to-day tasks (Owen et al. 2010). As such the utility of such exercises in strengthening self-regulation in the context of health protective behaviours may be questionable.

A growing body of research has also shown that aerobic training may enhance ECRs (Kamijo & Takeda, 2010; Masley, Roetzheim, & Gualtieri, 2009; Newson & Kemps, 2008; Stroth, Kubesch, Dieterle, Ruchsow, Heim, & Kiefer, 2009). However, given that initial increases in physical activity may be difficult to achieve among those with low self-regulatory abilities, developing methods for augmenting self-regulatory success may be warranted.

2.7 Implementation Intentions

Recently, it has been demonstrated that individuals can compensate for ECRs by implementing simple goal-setting strategies (Hall et al., 2011). After forming specific action plans for physical activity, individuals with lower ECRs exhibited a significant increase in intention-behaviour correspondence when environmental conditions made physical activity goal achievement difficult. These volitional plans, known as implementation intentions (Gollwitzer, 1993) may be one avenue for bolstering goal attainment in older adults who may be subject to declines in ECRs.

In contrast to goal intentions that indicate what an individual intends to achieve ("I plan to initiate and maintain a physical activity routine"), implementation intentions are if-then plans, that specify when and where an individual will enact particular behaviours in the service of the goal intention ("Every day when I finish work I will go to the gym"; Gollwitzer, 1993; 1999; Sheeran et al., 2005). In other words, implementation intentions facilitate goal achievement by invoking a behavioural response ("I will go to the gym") when a specified cue is encountered ("Every day when I finish work"; Gollwitzer, 1993; 1999). In this way, implementation intentions strengthen intention-behaviour relationships through the delegation of behavioural control to a situational cue that engenders behaviour in a relatively automatic fashion (Webb & Sheeran, 2007). Given that the behaviour of those with lower ECRs may be more highly determined by immediate environmental and situational cues, implementation intentions may provide a unique benefit to those with weaker ECRs (Hall et al., 2011). By forming this link between a situational cue and subsequent behaviour, implementation intentions may diminish the self-regulatory burden normally carried by ECR (Cohen, Bayer, Jaudas, & Gollwitzer; 2007; Webb & Sheeran, 2003).

2.8 Implementation Intentions and Health Behaviour

Due to their beneficial effects on goal attainment, implementation intentions have been shown to be effective in facilitating different health-protective behaviours. Accordingly, implementation intentions have demonstrated effectiveness in smoking cessation (Armitage, 2008b; Armitage & Arden, 2008), promoting cancer screening (Sheeran & Orbell, 2000; Steadman & Lyn, 2004), skin cancer prevention (van Osch, Reubsaet, Lechner, & de Vries, 2008) blood-glucose monitoring (Liu & Park, 2004), condom-carrying behaviour (Arden & Armitage, 2008), and decreasing alcohol consumption (Armitage, 2009).

Yet, much of the research investigating the role implementation intentions have in health-relevant behaviour has examined their utility in the domain of diet and physical activity.

Implementation intentions have been effective in increasing healthy food consumption (Armitage, 2007a; Chapman, Armitage, & Norman, 2009; Kellar & Abraham, 2005; Stadler, Oettingen, & Gollwitzer, 2010; Verplanken & Faes, 1999), reducing dietary fat intake (Armitage, 2004), ignoring cravings for unhealthy foods (Achtizer, Gollwitzer, & Sheeran, 2008) and facilitating healthier snacking behaviour (Adriaanse, de Ridder, & de Wit, 2009; Tam, Bagozzi, & Spanjol, 2010). The effects can be long lasting with one study reporting beneficial effects on diet over a two year period (Stadler et al., 2010).

A growing body of literature has also spoken to the potential use of implementation intentions for promoting physical activity. Interventions that include a volitional component that include implementation intention instructions have been shown to significantly increase physical activity where a purely motivational intervention had failed to do so (Milne, Orbell, & Sheeran, 2002; Prestwich, Lawton, & Connor, 2003). Spontaneous physical activity implementation intentions that were not laboratory-induced have also been effective (Brickell, Chatzisarantis, & Pretty, 2006; Ziegelmann, Luszczynska, Lippke, & Schwarzer, 2007). This self-regulatory strategy has shown efficacy in clinical settings with cardiac (Luszczynska, 2006) and spinal cord injury (Latimer, Ginis, & Arbour, 2006; Ziegelmann et al., 2007) rehabilitation patients where an increase in physical activity was associated with physical activity implementation intention formation. As with the dietary literature, the effects of implementation intentions on physical activity can remain long after the initial intervention, remaining weeks or months post-intervention (Latimer et al., 2006; Luszczynska, 2006). For example, Ziegelmann et al. (2007) reported the beneficial influence of implementation intentions on future physical activity over a 12 month period.

Although Gollwitzer (1999) originally conceptualized implementation intentions as action plans that stipulate when, where, and how an individual will successfully perform a goal-relevant behaviour, the literature assessing how implementation intentions impact physical activity behaviour exhibits varied methods of delivering the implementation intention intervention. Many investigations have supplied implementation intentions in a basic and brief format asking participants to report when and where they plan to implement their physical activity goal (Arbour & Ginis, 2009; Kwak, Kremers, van Baak, & Brug, 2007; Milne, 2002; Prestwich et al., 2003; Prestwich & Perugini, 2010).

Others have employed relatively intensive delivery methods involving guided assistance of implementation intention formation through one-on-one consultation (Luszczynska, 2006; Sniehotta, Scholz, & Schwarzer, 2006). For example, Luszczynska (2006) instructed participants as to what an implementation intention should be comprised of before they formed their plans. Once participants had completed their implementation intentions form, participants screened the form with the assistance of an interviewer who provided supportive feedback and complimented the participant on the formation of their implementation intention plan.

Given the varied delivery methods of physical activity implementation intentions, the literature suggest a robust effect of implementation intentions on physical activity. With their demonstrated efficacy and their potential to be delivered in a simple and brief format, these self-regulatory strategies may be feasibly added to public health interventions aimed at increasing physical activity levels.

3.0 Study Rational

3.1 Gaps in the Literature

Despite being a strong predictor of behaviour (Sheeran, 2002, Godin & Connor, 2008) there is still much to be understood surrounding the influence that intentions have on individual health behaviour. The role of implementation intentions (Milne, Orbell, & Sheeran, 2002; Prestwich, Lawton, & Connor, 2003; Luszczynska, 2006) in the facilitation of health-protective behaviour from intentions is gaining more attention. However, when considering the literature exploring the application of implementation intentions to health behaviour, few studies have specifically assessed their use in facilitating physical activity in a healthy older adult population. As a group that has much to benefit from health behaviour interventions, it is important that their use in facilitating physical activity in this population is examined.

In addition, although the ability to inhibit prepotent responses (one category of ECRs; Miyake et al., 2000) has been demonstrated to be related to physical activity goal attainment in young adults (Hall et al., 2008b), few studies have looked at the role of ECRs in successful health behaviour performance in older adults. It is yet to be seen if ECRs are important in physical activity goal attainment in older adults and which categories of ECR (inhibition, task-switching, working memory) are most influential. Given the declines in ECRs that are observed with increasing age, individual differences in ECRs may be a particularly important predictor of health behaviour in older adults as individual variability in cognition will be wider than in a younger population.

3.2 Purpose

The purpose of the present investigation was to assess the effect of forming implementation intentions for physical activity in older adults with stronger and weaker ECRs.

Specifically, the first objective was to examine the effect of implementation intentions in facilitating physical activity in an older adult sample and whether forming implementation intentions increased intention-behaviour correspondence. The second objective was to examine the moderating influence of ECRs on the intention-behaviour relationship. The last objective was to assess whether implementation intentions exerted a differential effect on intention behaviour relationships in those with higher and lower ECRs.

3.3 Hypotheses

It was hypothesized that those who formed physical activity implementation intentions would exhibit the greatest level of physical activity when compared to a control and no-treatment group. It was further hypothesized that the physical activity implementation intention group would have higher intention-behaviour correspondence relative to the control and no-treatment groups (i.e., reflecting more successful self-regulation). It was also hypothesized that ECRs would moderate the extent that intentions predict physical activity. Specifically those with higher ECRs would exhibit stronger intention-behaviour correspondence relative to those with lower ECR. Finally, a 3-way interaction of intention strength, ECR, and treatment condition was hypothesized; that implementation intentions would strengthen intention-behaviour correspondence to the greatest extent in those with lower ECR.

The investigation also included secondary hypotheses. It was hypothesized that due to cognitive decline with age, ECRs would moderate intention-behaviour relationships differentially by age. Similarly, it was hypothesized there would be a differential effect of implementation intentions on intention-behavioural relationships by age.

4.0 Methods

4.1 Sample

One hundred and ten older adults between 61 and 89 years of age (*M*=74.42, *SD*=6.90) were recruited from a university research participant database for older adults (Waterloo Research in Aging Participant Pool) as well as from the surrounding community. The latter recruitment took place via placement of flyers posted and presentations to local community venues (e.g., at community centres, sports centres, churches, laundromats, grocery stores, senior homes, apartment complexes, farmer's markets). All participants were functionally mobile, had correct-to-normal vision and were not suffering from cognitive, neurologic or motor problems.

4.2 Procedure

Eligible individuals were contacted via telephone and provided with information regarding the research project (see Appendix A). After receiving the summary of the study and having any questions answered, eligible individuals were asked if they would be interested in participating. Once the decision to participate was made, an in-laboratory session was scheduled with the experimenter (See Fig 1.) and directions to the laboratory building and nearby parking locations were provided.

Upon arrival to the lab, a detailed overview of the study was provided as well as confirmation to the participant that the project has received full ethics clearance by the University of Waterloo Office of Research Ethics. An information letter along with an informed consent form (see Appendix B) was distributed to the participant and any questions that the participant had were answered.

Once the participant was ready to begin the study, the researcher administered a measurement of waist circumference. The top of the hip bone was located and a measuring tape was applied closely and evenly at that level while the participant was exhaling to provide an accurate measurement. Participants then completed three computer tasks to assess different facets of executive function as described in Miyake at al. (2000): behavioural inhibition, task-switching and working memory. Participants first completed a task measuring behavioural inhibition (Go/No-Go Task), then completed a task assessing task-switching (Number-letter Task), followed by a working memory task (Keep Track Task). Next, participants were asked to complete a computer-delivered questionnaire that contained items pertaining to socio-demographic information and TPB variables (Ajzen, 1991). Participants provided self-report measures of baseline physical activity intention and behaviour. Finally, the participants were randomly assigned one of three study conditions: experimental (weekly implementation intentions for physical activity), control (weekly implementation intentions for reading), or a no-treatment condition. Accordingly, those in the experimental and control groups completed implementation intention tasks for physical activity and reading respectively.

Once this was completed, participants were provided with an Actical accelerometer, which was worn on the hip and secured in place using a nylon belt. Before leaving, participants received reimbursement for their involvement in the study in the form of a $20 University of Waterloo Retail Services gift card, and were reminded about the upcoming weekly telephone surveys.

During each of the 4 follow-up telephone sessions, participants provided self-reports of physical activity behaviour and intentions for the week. Those in the experimental and control groups refreshed implementation intentions for the upcoming week. After the fourth and final follow-up interview, participants received feedback regarding the nature of the study (see Appendix C).

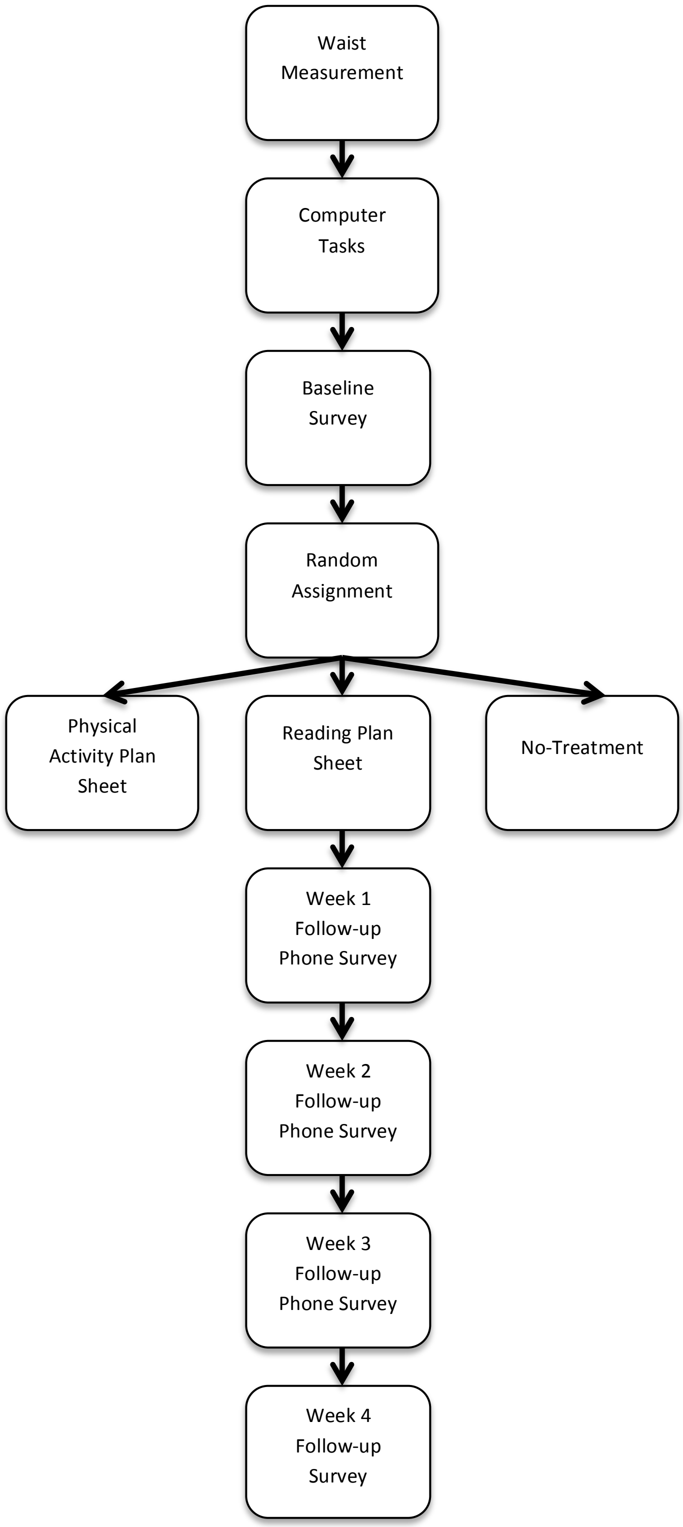

Fig. 1. Study Protocol Summary

4.3 Measures and Materials

4.3.1 Self-Report Physical Activity Intention and Behaviour Measure

Based on the format used in Sallis et al.'s (1985) Stanford 7-day Recall, participants completed self-report measures of physical activity intentions for the baseline and all follow-up sessions by reporting how much physical activity they planned to engage in for the "next 7 days" (see Appendix D). Behaviour was assessed similarly by asking participants to report how much physical activity they engaged in over the "past 7 days". Both the physical activity intention and behaviour measures have been used previously by Hall et al. (2008b). The measure possesses strong test-retest reliability (r=.83, $p\leq$.001; Sallis et al. 1985), and has demonstrated criterion validity when compared to an accelerometer (r=.73, $p\leq$.001; Johnson-Kozlow, Sallis, Gilpin, Rock, & Pierce, 2006).

4.3.2 Accelerometer-based Physical Activity Measure

To provide a non-self report measure of physical activity, participants wore an Actical Physical Activity Monitor, an accelerometer that was fastened at the level of the hip in accordance with recommendations from a review by (Trost, McIver, & Pate, 2005). The accelerometer collects motion data primarily over one plane of movement (Heil, 2006). The device was worn for 7 days and bodily acceleration data was stored every 15 seconds as activity counts. From this, average daily activity counts were calculated to represent the measure of physical activity in those that wore the device for at least 4 of the 7 days. Prior studies have confirmed that accelerometers provide reliable estimates of energy expenditure with a 3 to 4 day sampling of activity counts (Matthews, Ainsworth, Thompson, & Bassett, 2002). The Actical accelerometer used in the present investigation has demonstrated superior intrainstrument and interinstrument reliability when compared to other accelerometers in common use (Eslinger & Tremblay, 2006).

4.3.3 Executive Function Measures

Go/No-Go Task

The go/no-go (GNG) task is a reaction time task that assesses the ability to inhibit prepotent responses to stimuli (Jodo & Kayama, 1992). In the current version of the task, participants were seated at a desktop computer and instructed to press a button on a response box if a lower case letter was shown, but refrain from pressing the button if an upper case letter was shown. Participants were asked to respond as quickly as possible without making mistakes. After completing a practice block of twelve trials, participants encountered eight more blocks (four with a preponderance of upper case and four with a preponderance of lower case) that were each comprised of 60 trials. Performance on the GNG task has been shown to be correlated with prefrontal cortex and anterior cingulate cortex function (Kiefer, Marzinzik, Weisbrod, Scherg, & Spitzer, 1998). As such, both reaction time and the number of correct responses were calculated to assess inhibition (specifically behavioural inhibition), with shorter reaction times on correct trials indicating stronger inhibition and slower reaction times indicating weaker inhibition. As a result of the stronger emphasis on behavioural inhibition, the reaction times during blocks containing a predominance of upper case letters (the stimuli requiring a refrainment of response), was the primary indicator of inhibition, as has been used elsewhere (Hall, 2011).

Number-Letter Task

The number-letter (NL) task that was developed by Rogers and Monsell (1995) and later amended by Miyake et al. (2000) was employed to assess task-switching. Participants were shown a number-letter pair (i.e., “7R”) in one of four quadrants. When the number-letter pair was presented in the lower two quadrants, participants were required to specify whether the letter was a vowel or a consonant by pressing the appropriate button. Similarly, when the number-letter pair was presented in the upper two quadrants, an indication of whether the number was odd or even was required. The task included three blocks: one block of 32 trials in which number-letter pairs were only presented in the upper two quadrants, one block of 32 trials in which the number-letter pairs were only presented in the bottom two quadrants, and one block of 128 trials in which number-letter pairs were presented in each of the four quadrants sequentially in a clockwise order. Performance on the NL task was assessed by determining the difference between reaction times of trials in the third block and the first two blocks which provided a measure of shift cost as outlined in Miyake et al. (2000).

Keep Track Task

The keep track (KT) task, modified from Yntema (1963) by Miyake et al. (2000), assessed the ability to update and monitor working memory. Participants were asked to hold in memory relevant information while new information was presented. In each trial, participants were presented with a random sequence of words (e.g., bird, green, aunt, Canada, nickel, near). Once the words had been presented on the screen, they were asked to try to recall the most recent words shown that fell within different categories (e.g., animals, colors, relatives, countries, metals, distances) and write them down on a response sheet. In the initial two practice trials, participants were asked to recall the most recent words presented that fall within each of three categories. In the next three trials, participants were asked to recall the most recent words presented from each of four categories. The last trial required participants to try to recall the most recent words presented falling within five categories. The proportion of correct responses was used to assess working memory. The GNG task was delivered first, followed by the NL task, then the KT task.

4.3.4 Implementation Intentions Manipulation

Those randomly assigned to the experimental condition formed implementation intentions for physical activity goals (see Appendix E) and reading goals (see Appendix F) respectively. At baseline, participants were asked to describe their goal plan (i.e., “In the space below, please think about and describe when, where, and how you will achieve your goals.”). To facilitate thinking pertaining to possible obstacles to goal achievement, participants were next asked to write down what may prevent them from achieving their goals (i.e., “Think of any obstacles that may prevent you from achieving your goals.”). Participants were subsequently instructed to generate solutions to any reported obstacles (i.e., “What are some ways you may be able to overcome those obstacles?”). During each follow-up telephone survey, participants were asked to refresh their goal plans with the researcher by writing down again when, where, and how they would achieve their goal for the next week. The inclusion of the control condition was to determine if a physical activity-specific implementation intention goal facilitates physical activity above and beyond the mere act of forming an implementation intention for any goal.

4.3.5 Theory of Planned Behaviour measures

Behavioural intentions were measured through questions pertaining to theory of planned behaviour variables (Ajzen, 1991). Specifically, measures of social norms, attitudes, perceived behavioural control, and intention strength regarding physical activity were included in a questionnaire (see Appendix G). The measures were constructed in a similar format used by Courneya, Bobick, & Schinke (1999) to predict exercise behaviour.

Attitudes about physical activity were assessed via six counter-balanced 5-level Likert items. Each item began with the phrase, "Daily physical activity would be…" and was followed by 5 levels of responses measuring the expected pleasantness (extremely pleasant to extremely unpleasant), goodness (extremely good to extremely bad), positivity (extremely positive to extremely negative), amusement ("extremely fun" to "extremely boring"), satisfaction (extremely satisfying to extremely dissatisfying) and appeal (extremely appealing to extremely unappealing) of physical activity. The internal consistency was high with an alpha coefficient of .816. Social norms of physical activity was operationalized through the use of a 7-level Likert item that asked, "Do most people who are important to you think you should or should not engage in daily physical activity?" with potential responses ranging from "strongly think I should not" to "strongly think I should". Perceived behavioural control was measured through one item that asked, "How much control do you think you have over whether or not you engage in daily physical activity (from 0%-100%)?".

4.3.6 Physical Activity Self-Efficacy Measure

Bandura's (1977) concept of self-efficacy in the context of physical activity was measured. Adapting an exercise self-efficacy scale developed by Marcus, Selby, Niaru, and Rossi (1992), self-efficacy in the face of different obstacles to physical activity was measured. Each item began with the statement "I am confident I can participate in regular physical activity when:" followed by five different situations: "I am too tired; I am in a bad mood; I feel I don't have the time; I am on vacation; It is raining or snowing" (see Appendix H). The five-item scale employed an 11-level Likert format with responses ranging from "not at all confident" to "very confident". The authors report that the test-retest reliability of the measure is strong (.90). The internal consistency was also found to be strong with an alpha coefficient of .841.

4.4 Data Analytic Plan

To compensate for missing data, group mean imputation was used before the primary analysis on the self-report intention and behaviour measures. This was performed by imputing the mean of the intention and behaviour responses within each group for cases that were missing a response. The rationale for the imputation procedure was to improve statistical power. As a result of presenting distributions with skewness and kurtosis beyond the acceptable threshold of +/- 2, self-report intention and behaviour variables underwent square root transformations that successfully normalized the variables. The three treatment conditions were represented by 2 dummy variables as recommended by Aiken and West (1991). In the first, the experimental group was assigned a value of 1 while the control and no-treatment groups were assigned a value of 0. In the second dummy variable, the control group was assigned a value of 1 while the experimental and no-treatment groups were assigned a value of 0. To assess the impact of treatment condition on each of the 4 weeks, multivariate analysis of variance (MANOVAs) were conducted. Finally, hierarchical linear regression analyses were employed to assess the interactions of intention, ECRs, and treatment condition. To adjust for past behaviour, baseline physical activity levels was added in step 1. In step 2, intentions, measure of ECR and treatment condition were included. In step 3, the 2-way interactions of intention by ECR, intention by treatment condition, and treatment condition by ECR were added. In step 4, the 3-way interaction of intention, ECR, and treatment condition was included. The Aiken and West (1991) procedure for decomposing and graphing interactions, as well as testing the significance of simple slopes was followed, using +/- 1 SD to denote "high" and "low" levels of each target variable.

5.0 Results

The study sample comprised 110 older adults with a mean age of 74.42 (SD = 6.9); the majority of participants were female (68.2%) and university educated (55%). The mean waist circumference value (M = 37.16, SD = 4.25) was similar to national averages (McDowell, Fryar, Ogden, & Flegal, 2008) with male and female participants having a mean waist circumference of 38.96 (SD = 3.97) and 36.26 (SD = 4.13) inches respectively. Additional demographic information for the total sample is presented in Table 1.

Table 1

Sample Characteristics

	Total Sample (N = 110)	Experimental (N =37)	Control (N = 36)	No-treatment (N = 37)
Age[1]	74.42 (6.9)	74.50 (7.11)	74.14 (6.26)	74.62 (7.47)
Gender: women[2]	68.2	64.9	63.9	75.7
Married/common law[2]	57.8	52.8	55.6	64.9
College/university educated[2]	54.7	48.4	60.6	54.9
Household income: 60 000+[2]	42.6	33.3	43.3	50.9
Waist circumference[1]	37.16 (4.25)	37.3 (3.76)	37.12 (3.85)	37.24 (5.08)
GNG reaction time[1]	553.40 (65.37)	656.07 (69.91)	540.59 (53.45)	553.87 (70.38)
NL task performance[1]	515.75 (593.73)	617.29 (719.61)	422.48 (373.44)	614.75 (102.46)

KT task score[1]	.46 (.19)	.43 (.19)	.49 (.19)	.45 (.19)
Baseline vigorous activity[1]	1.67 (2.18)	2.22 (2.71)	1.47 (1.84)	1.22 (1.67)
Baseline activity intentions[1]	2.27 (3.44)	3.69 (4.76)	1.72 (2.26)	1.19 (1.78)

Note: [1]Mean (SD); [2]Percentage; GNG=Go/No-Go task, NL=Number-Letter task, KT=Keep Track task

Study drop-outs did not differ from those who remained in the study with respect to age ($F(2, 107)=.048$, $p=.827$), gender, ($F(2, 108)=.001$, $p=.981$), education ($F(2, 93)=.913$, $p=.342$), income ($F(2, 87)=.499$, $p=.482$), relationship status ($F(2, 107)=.033$, $p=.855$), waist circumference ($F(2, 94)=.000$, $p=.990$), baseline physical activity intentions ($F(2, 98)=.935$, $p=.336$), past behaviour ($F(2, 97)=.052$, $p=.821$), NL task performance ($F(2, 104)=.766$, $p=.383$), and KT task scores ($F(2, 102)=.003$, $p=.957$). Drop-outs did differ on GNG reaction time ($F(2, 106)=5.421$, $p=.022$), exhibiting shorter reaction time than those who remained in the study.

Study drop-outs were not significantly different in regards to physical activity attitudes ($F(1, 107)=.073$ $p=.788$), norms ($F(1, 106)=.005$, $p=.946$), perceived behavioural control ($F(1, 107)=.185$ $p=.668$), or self-efficacy ($F(1, 102)=.619$ $p=.433$).

Finally, the three study groups did not differ on age ($F(2, 106)=.047$, $p=.954$), gender composition ($F(2, 107)=.715$, $p=.491$), educational attainment ($F(2, 92)=.947$, $p=.392$), household income ($F(2, 86)=1.678$, $p=.193$), relationship status ($F(2, 106)=.003$, $p=.997$), waist circumference ($F(2, 93)=.009$, $p=.991$), GNG reaction time ($F(2, 105)=1.269$, $p=.285$), NL task performance ($F(2, 103)=.966$, $p=.384$), KT task scores ($F(2, 103)=1.011$, $p=.368$), or baseline physical activity behaviour ($F(2, 96)= 1.941$, $p=.149$). However, intention did differ between the treatment groups (F(2, 97)=5.45, p=.006) with the experimental group having higher mean intentions (M=3.69) than the control (M=1.72) and no-treatment groups (M=1.19). Study groups also did not vary statistically on physical activity attitudes toward physical activity (F(2, 106)=1.363 p=.260), physical activity norms (F(2, 105)=.142 p=.868), perceived behavioural control (F(2, 106)=.399 p=.672), or self-efficacy (F(2, 101)=.251 p=.778).

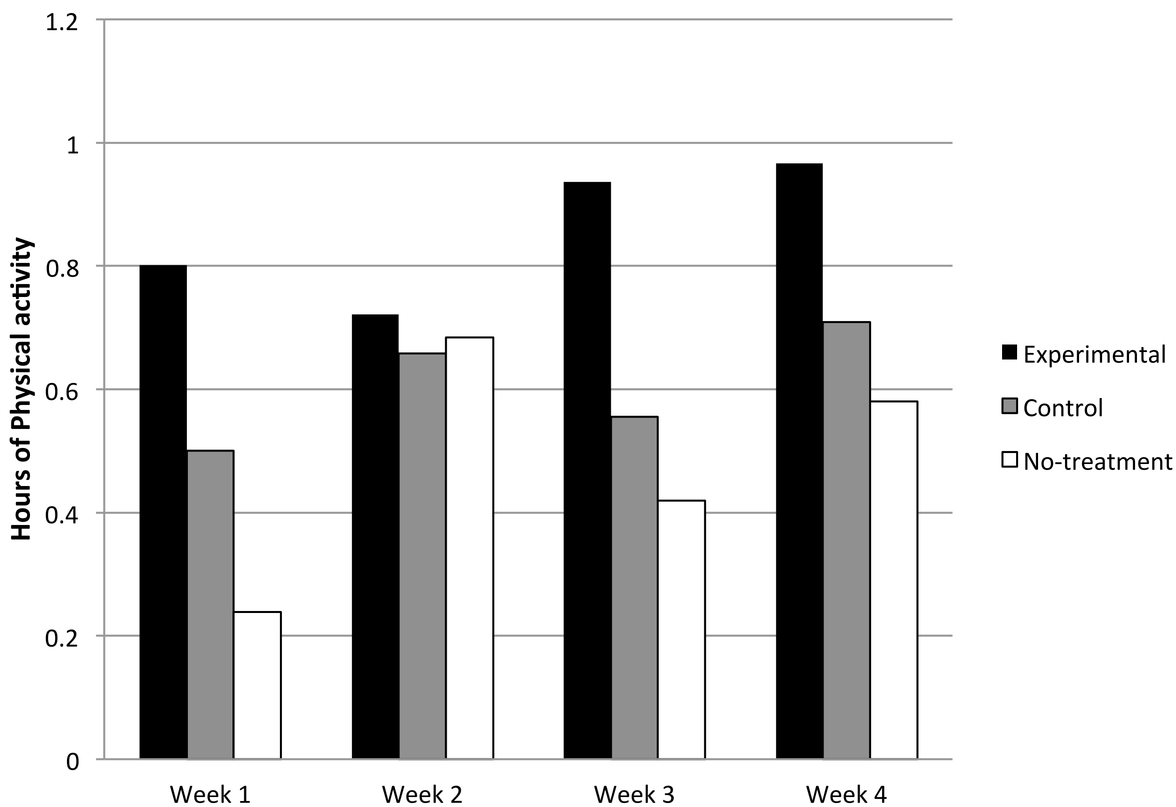

Fig. 2. Treatment effect for each follow-up week (marginal means; N=110)

5.1 Primary Analyses

5.1.1 Basic treatment effect

A treatment effect on 1-month self-reported physical activity levels emerged when controlling for baseline behaviour (ΔR^2=.041, F(2,105)=3.823, p=.025) with observed power of

.816. Multivariate analyses of variance (MANOVA) revealed that the effect of group attained significance at week 1 ($F(2)=6.986$, $p\leq.001$), week 3 ($F(2)=4.418$, $p=.014$), and marginally for week 4 ($F(2)=2.445$, $p=.092$; see Fig. 2). The effect for week 2 did not attain statistical significance ($F(2)=.061$, $p=.941$).

Planned comparisons by week revealed that the experimental group demonstrated significantly greater physical activity levels over week 1 ($p\leq.001$) and week 3 ($p=.005$), and week 4 ($p=.039$) when compared to the control group and no-treatment group. When compared specifically to the control group, the experimental group demonstrated significantly greater physical activity levels over week 1 ($p=.047$) and week 3 ($p=.037$) while showing significantly higher physical activity levels for weeks 1 ($p\leq.001$), 3 ($p=.005$), and 4 ($p=.032$) when compared to the no-treatment group. A comparison of the control group and the no-treatment group showed no significant differences in physical activity levels for weeks 2 ($p=.890$), 3 ($p=.453$), or 4 ($p=.469$), and only a marginal effect for week 1 ($p=.086$). Hierarchical regression analysis was also employed to determine if a basic treatment effect existed for 1-week accelerometer-based average activity counts; however, no treatment effect was detected ($\Delta R^2=.005$, $F(2,84)=.206$, $p=.814$).

When examining 1-month self-reported physical activity, main effects of treatment condition (above) and intention ($\beta_{INT}=.847$ $t=22.686$, $p\leq.001$) were qualified by a significant 2-way interaction of intention and treatment condition ($\Delta R^2=.006$, $F(2,102)=3.660$, $p=.029$;see Fig. 3). Intentions predicted physical activity most strongly in the experimental group ($\beta_{INT}=.546$, $t=17.266$, $p\leq.001$) followed by the control group ($\beta_{INT}=.413$, $t=9.235$, $p\leq.001$), and the no-treatment group ($\beta_{INT}=.280$, $t=3.960$, $p<.001$).

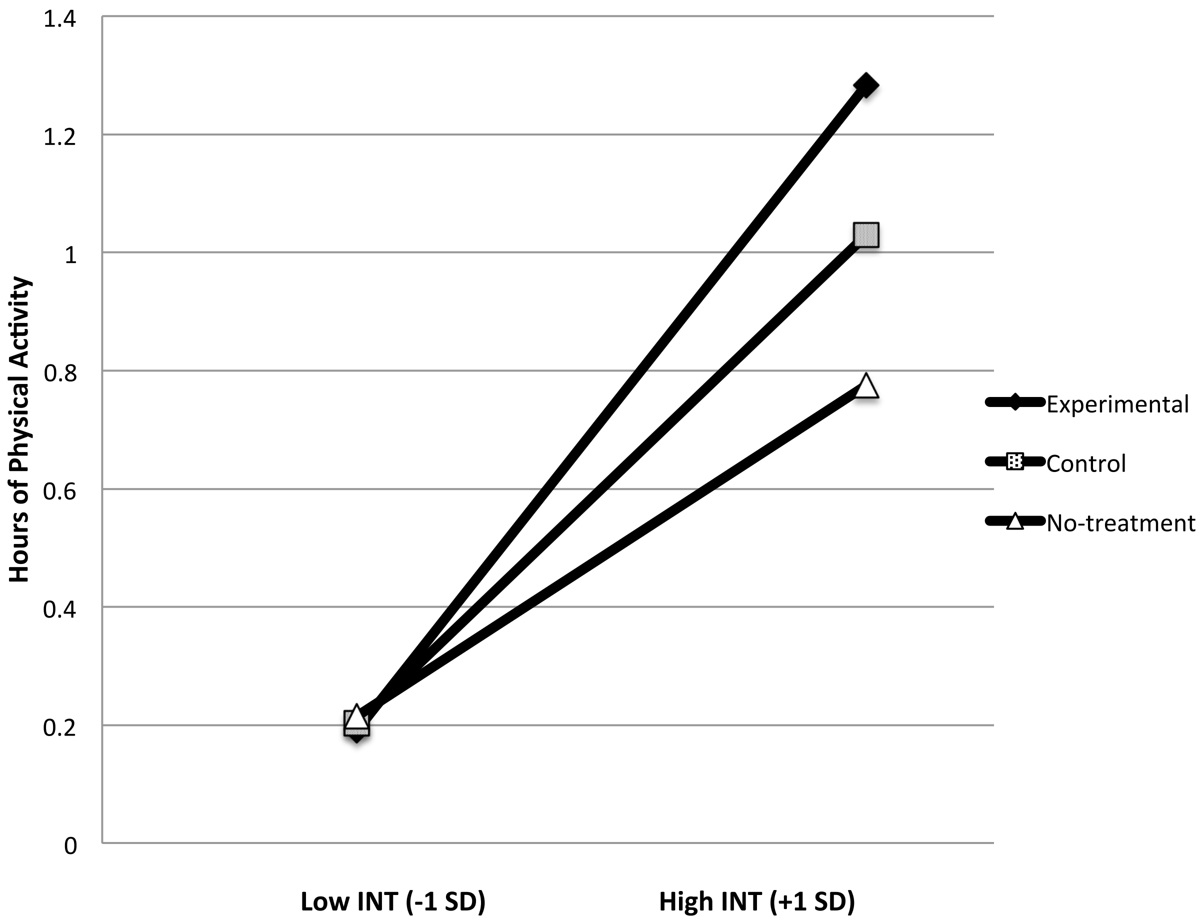

Fig. 3. Intention-behaviour correspondence by treatment condition (standardized variables; *N*=110)

5.1.2 Behavioural inhibition

For the models involving GNG reaction times, the main effects of intention (β_{INT}=.847 t=22.482, p<.001) and treatment condition (ΔR^2=.041, F(2,105)=3.823, p=.025) on 1-month self-reported physical activity were qualified by a 2-way interaction of intention and treatment condition (ΔR^2=.006, F(2,102)=3.660, p=.029) when adjusting for baseline physical activity. A

3-way interaction of intention strength, treatment condition, and GNG reaction time was not significant after adjustments for baseline physical activity (see Appendix I for null findings).

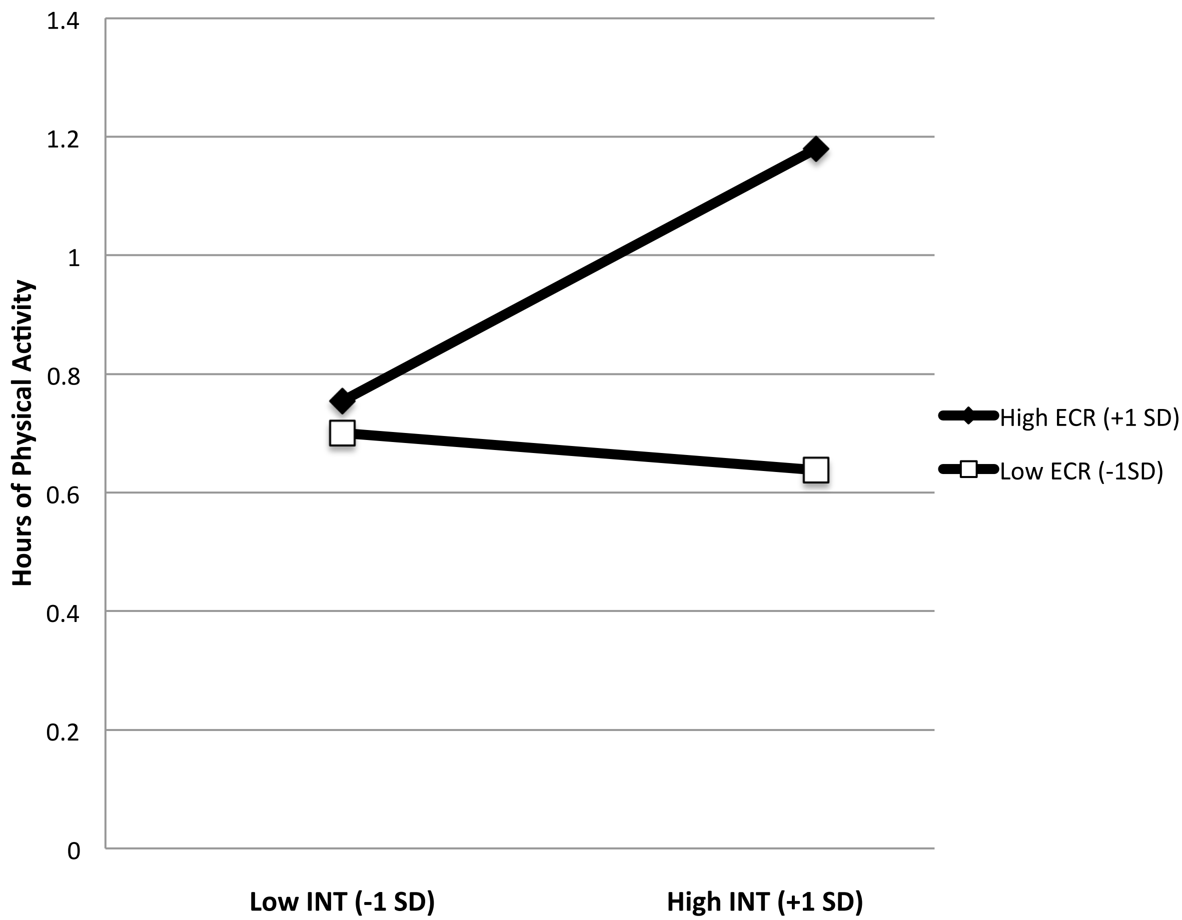

Fig 4. Intention-behaviour correspondence for participants with high and low behavioural inhibition (standardized variables; *N*=86)

Hierarchical regression analyses revealed a marginal 2-way interaction of intention and GNG reaction time ($\beta_{INTxGNG}$=-1.22, *t*=-1.840, *p*=.070) on accelerometer-based average activity counts after controlling for baseline physical activity (Fig. 4). Specifically, intentions predicted average activity to a greater extent in those with high behavioural inhibition (β_{INT}=.213) than those with low behavioural inhibition (β_{INT}=-.031). There were no significant two- or three-way interactions involving GNG reaction times after adjusting for baseline physical activity.

5.1.3 Task-switching

For the models including NL scores, the main effect of intention (β_{INT}=.841, t=19.538, $p \leq .001$) and treatment condition (ΔR^2=.041, F(2,105)=3.823, p=.025) on 1-month self-reported physical activity was qualified by a 2-way interaction of intention and treatment condition (ΔR^2=.006, F(2,102)=3.660, p=.029) when adjusting for baseline physical activity. No two- or three-way interactions involving NL were significant after adjusting for baseline physical activity.

There were no main effects, 2-way interactions, or 3-way interactions when assessing predictors of accelerometer-based average activity counts when controlling for baseline physical activity.

5.1.4 Working memory

For the models involving KT scores, a main effect of intention (β_{INT}=.851, t=21.871, $p \leq .001$) and treatment condition (ΔR^2=.041, F(2,105)=3.823, p=.025) was qualified by a 2-way interaction of intention and treatment condition (ΔR^2=.006, F(2,102)=3.660, p=.029) when adjusting for baseline physical activity. No additional two- or three-way interactions involving KT were significant.

A main effect of KT task performance on accelerometer average activity counts emerged (β_{KT}=.223, t=1.975, p=.052) after controlling for baseline physical activity. No two- or three-way interactions predicting accelerometer activity counts were present.

5.2 Secondary Analyses

5.2.1 Age

The effect of implementation intentions on 1-month physical activity when considering age was assessed. Despite a main effect of age (β_{AGE}=-.162, *t*=-2.238, *p*=.027), there was no significant 2-way interactions of age and treatment or intention and age after adjustments for past behaviour. There was also no detection of a 3-way interaction of intention, age, implementation intentions after adjusting for past behaviour. These findings indicated that age did not influence the extent to which intentions and treatment condition predicted 1-month self-reported physical activity.

Similarly, when examining accelerometer activity counts, no significant two interactions of treatment condition and age, or intentions and age were found after controlling for baseline physical activity. The three way interaction of intentions, age, and treatment condition was also not significant when adjusting for baseline behaviour. This indicated that the extent that intention and treatment condition influenced accelerometer-based average activity counts was not affected by age.

When assessing the influence of age and ECR function, each category of ECR (behavioural inhibition, task-switching, working memory) was examined separately with age to predict 1-month self-reported physical activity and accelerometer-based average activity counts. No significant 2-way interactions of intention and age or ECR and age were found after adjustments for baseline physical activity when predicting 1-month physical activity levels. There was also no presence of a significant 3-way interaction of intention, age, and ECR after adjusting for past behaviour. Similarly no 2-way interactions or 3-way interactions were detected when examining intention, age and ECR when predicting accelerometer activity counts after adjusting for baseline physical activity.

6.0 Discussion

In the present investigation, it was hypothesized that forming implementation intentions for physical activity would increase physical activity levels in older adults, and that implementation intentions would increase intention-behaviour correspondence. It was also hypothesized that ECRs would moderate the intention-behaviour relationship; those with strong ECRs would demonstrate greater intention-behavior correspondence relative to those with weak ECRs. Finally, it was hypothesized that implementation intentions would affect intention-behaviour correspondence differentially for those with strong and weak ECRs.

Implementation intentions were effective for increasing physical activity among community-dwelling older adults. Those who received implementation intentions for physical activity showed significantly greater increases in physical activity than those receiving a control goal setting intervention or no treatment. This effect attained statistical significance at weeks 1, 3, and 4, though not in week 2.

A 2-way interaction of intention and treatment condition qualified the treatment effect. Those in the experimental group exhibited greatest intention-behaviour correspondence. These findings support the contention that implementation intentions can help increase physical activity levels in older adults, and that the effects may emerge via increased self-regulatory success (i.e., stronger intention-behaviour correspondence).

The treatment effects observed with the self-report measures were not replicated with the accelerometer measure. There are a number of reasons why this may be the case. First, accelerometers assess all forms of movement, some of which involve incidental movements that differ dramatically in intensity from the intense activities that we describe as "exercise." In fact, the inability of accelerometers to distinguish among types of activities is one of their major shortcomings as a physical activity assessment tool. Given that we did find effects for self-reported vigorous physical activity, it may be the case that implementation intentions have stronger effects on more intense forms of activity, but that the effects are "washed out" in accelerometer assessed activity, which includes more incidental forms of movement. It is also possible that there were social desirability influences on the experimental group, or expectancy effects, which could also produce the appearance of a treatment effect on self-reported outcomes selectively. However, even accelerometers are subject to expectancies (Motl et al. 2011) and so this does not necessarily provide a compelling account of the divergence between self-report and accelerometer based outcomes. One final possibility is that power to detect effects may have been lower given the relatively small sample size; combined with the diluting effect of assessing all motion types, this could have reduced the probability of finding an effect on this measure.

Despite the lack of treatment effect, a marginally significant interaction of intention by behavioural inhibition emerged using accelerometer assessed activity. Specifically, intentions predicted behaviour to the greatest extent in those with strong behavioural inhibition compared to those with weak behavioural inhibition. These findings suggest that of the facets of ECR examined, behavioural inhibition may have a unique role in goal attainment in the context of physical activity. This finding supports previous theoretical perspectives highlighting behavioural inhibition as relevant for the performance of health-protective behaviour given its temporal dimensionality (Hall & Fong, 2007). In other words, health goal achievement may be related to the ability to inhibit prepotent responses to immediate cues that may conflict with successful behavioural performance (ie., feeling too tired to exercise). This result also replicates past empirical findings of the intention-moderating effect of inhibition for physical activity performance (Hall et al., 2008).

Interestingly, working memory was a significant predictor of average activity counts with those demonstrating higher scores in the KT task exhibiting a higher level of physical activity compared to those with lower scores after controlling for baseline behaviour. This may suggest that working memory may provide greater capacity to maintain an exercise regimen.

The present investigation replicated past experimental studies demonstrating the efficacy of an implementation intention intervention for increasing physical activity levels (Milne, Orbell, & Sheeran, 2002; Prestwich, Lawton, & Conner, 2003; Prestwich, Perugini, & Hurling, 2010) while extending these findings to a relatively old sample (mean age = 74.42). In addition, as mentioned, the results are congruous with prior research suggesting that ECRs (particularly behavioural inhibition) moderate the influence that intentions have on prospective behaviour (Hall et al., 2008), providing further support for the self-regulatory function behavioural inhibition may have in goal-oriented health behaviour (Hall & Fong, 2007).

Secondary Findings

When considering the secondary analyses, age was found to be a significant predictor of physical activity with younger participants exhibiting the highest levels of physical activity. However, this effect was not qualified by an interaction of age with intentions, ECR, or treatment condition. Put differently, the influence of intentions, ECR and treatment condition on physical activity was not found to vary with age within the older adult sample examined.

Strengths and limitations

There are several strengths for the present investigation. First, the experimental design allowed for the observation of the causal effect of implementation intentions on physical activity which would not have been possible using a correlational design. Also, for the measurement of physical activity, both a 1-month follow-up period of weekly self-report physical activity assessments and a 1-week measure of accelerometer-measured physical activity was utilized. This allowed for greater methodological rigor in ascertaining the dependant variables when compared to investigations exclusively conducting self-report methodology to measure physical activity levels. Finally, when assessing ECR function, the employment of multiple computer-administered tasks provided a broad sampling of the different components of ECRs. This allowed for the assessment of each specific ECR category (inhibition, task-switching, working memory) and the extent that they were related intention-behaviour relationships.

There are also some limitations to the current study. As mentioned above, a treatment effect on accelerometer-based average activity counts was not detected. Although one possibility was that an effect may have been washed out by low intensity physical activity detected by the accelerometer throughout the day, another possibility is that the current sample may not have provided the power necessary to detect a treatment effect on average activity counts due to a relatively small size. This may also be a possibility for the absence of detected 3-way interactions.

Implications and future directions

The findings provide preliminary evidence of the efficacy of an implementation intention intervention for increasing physical activity in older adults. Given its brief format, a public health intervention including this planning strategy may be feasible for increasing physical activity among older adults. As such, future research examining ways to adapt implementation intention interventions to make them more readily diffusible should be conducted. These findings also suggest the need for research further delineating the influence of the different ECRs on the intention-behaviour relationship in the context of health behaviour. Although behavioural inhibition appears to be selectively relevant to intention-behaviour relationships for physical activity as shown here and in prior research (Hall et al. 2008b), future research is necessary to determine if behavioural inhibition is important in the context of other health-related behaviours or if other ECR facets may be relevant.

Conclusions

In summary, the efficacy of an implementation intention intervention for increasing physical activity in older adults with varying levels of ECR was examined through the employment of both self-report and accelerometer measures. This effect was investigated while considering the moderating influence of intention strength and three ECR facets (behavioural inhibition, task-switching, working memory). Implementation intentions were found to be effective for increasing physical activity levels over a 1-month follow-up period. The behaviour facilitating effects of implementation intentions appeared to operate via increased self-regulatory success in the experimental group compared to the other study groups. Of the ECR facets assessed, only behavioural inhibition was found to moderate the intention-behaviour relationship for accelerometer assessed physical activity; those with stronger behavioural inhibition had greater intention-behaviour correspondence relative to those with weaker behavioural inhibition. There was no evidence, however, that ECRs interacted with implementation intentions. Overall, the current findings suggest that implementation intentions are effective in increasing physical activity levels in a healthy older adult population and that behavioural inhibition may be selectively important for physical activity goal attainment, regardless of goal setting strategy.

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APPENDIX A: Telephone Script

Telephone Recruitment Script

Hello, may I speak to **(name of potential participant)**?

Hi, my name is **(name of researcher)** and I am a graduate student in the Health Studies and Gerontology department at the University of Waterloo. I am currently conducting a research project under the supervision of Dr. Peter Hall who is one of the researchers associated with the Waterloo Research in Aging Participant Pool that you are registered in as a potential research participant.

The reason I'm calling is because I am currently seeking volunteers from the Waterloo Research in Aging Pool to be participants in a study that is looking at how psychological processes contribute to health behaviour patterns over time. Would this be something you would be interested in?

(If no) Thank you for your time, good-bye.

(If yes) This study consists of one in-lab session where you will need to come into the lab, and four weekly follow-up phone surveys. In the in-lab session, your waist circumference will be measured with a measuring tape and you will be asked to complete a questionnaire pertaining to demographic information, physical activity intentions, attitudes and behaviour and to complete three computer tasks that assess cognitive abilities. You will be asked to form physical activity plans as well. This portion of the study will take about 1 hour to complete. During the follow-up sessions, you will be asked about your physical activity attitudes, habits, and behaviour. For your participation in the study, you will be compensated with a $20 gift card and any parking costs will be covered.

This project has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. Would you be interested in participating?

(If no) Thank you for your time, good-bye.

(If yes) Great, we appreciate your interest in the study. I have openings in our schedule to meet with you **(days and times available)**. Would any of these times work for you?

Great, I'm going to tell you where the in-lab session takes place. Do you have a paper and pen available? My name again is (name of researcher) and we will meet in the Burt Matthews Hall at the University of Waterloo. Burt Matthews Hall is located right at the Columbia Road entrance of the University. If you are driving, there is a parking lot (Lot M) just to the right of the building. I will meet you by the doors at the front of the building just off the main road. And again, the time we are meeting is **(time of session).**

If you find this appointment time no longer works for you, feel free to call me back at this number: **(lab number and extension).**

Do you have any questions at all?

Great, Thanks for your participation in this study and I look forward to meeting you in person.

APPENDIX B: Information and Consent Letter

Information and Consent Letter (Experimental Condition)

Title: Intentions and Physical Activity Behaviour

Investigators:

Student Investigator: Chris Zehr (czehr@uwaterloo.ca, 519-888-4567 ext. 38180)

Faculty Supervisor: Dr. Peter Hall (pahall@uwaterloo.ca, 519-888-4567 ext. 38110)

You have been invited to participate in a research project assessing how cognitive processes influence physical activity behaviour. The investigation is composed of one in-laboratory session and four smaller sessions delivered over the telephone.

In the laboratory session of this study, your waist circumference will be measured. To do this, using your fingers, you will locate where the top of your hip bone is. You will then place a flexible measuring tape evenly around your body at this level and provide the reading to the researcher. You will then be asked to complete a number of questionnaires pertaining to demographics and intentions, attitudes, and personal behaviour regarding physical activity. Moreover, you will be asked to form a physical activity action plan for the future.

You will also be asked to complete three computer tasks that assess cognitive ability. The first computer task will ask you to press a button when a lower case letter is presented on the screen and refrain from pressing the button when an upper case letter is presented. The second computer task will sequentially present words that belong in different categories. You will then be asked to try to remember the last word presented from each category. In the final computer task you will be shown a number-letter pair in one of four square spaces. When the number-letter pair is presented in the lower two squares, you will be asked to specify whether the letter is a vowel or a consonant by pressing the appropriate button. Similarly, when the number-letter pair is presented in the upper two squares, you will be asked to indicate whether the number was odd or even.

Before you leave, you will be fitted with an accelerometer with a strap around your hip that will measure physical activity levels that we ask that you wear for the next seven days except during sleep and when you are in contact with water.

The laboratory session will be followed by four weekly follow-up sessions where you will be asked again to report your exercise behaviour by telephone. As well, we ask that you return the accelerometer to the laboratory after the seventh day of wearing it.

The total time commitment for the study is 2 hours (1 hour for the initial laboratory session, and four 15 minute follow-up sessions). Participants may benefit from gaining knowledge regarding how behavioural health research is performed as well as learning about psychological determinants of health. If you have been advised by your physician not to take part in physical activity or have a health condition that limits your involvement in physical activity, then you should not participate in this study.

For participation in the study, you will receive a $20 grocery gift card even if you decide to withdraw early from the study. All information acquired for the study will be kept indefinitely in the University of Waterloo Social Neuroscience and Health Lab where only authorized researchers will have access. Any electronic information will be retained on a secure password-protected server. All identifying information will be removed.

Your participation is totally voluntary and you may withdraw your participation from this study or decline from responding to any questions asked with no penalty whatsoever. Please direct any questions you have to the researcher or contact Chris Zehr at 519-888-4567 ext. 38180. This study has been reviewed by, and has received ethics clearance from the Office of Research Ethics at the University of Waterloo. If you have any questions or concerns regarding the study, please contact Dr. Susan Sykes, Director, Office of Research Ethics at ssykes@uwaterloo.ca, 519-888-4567, Ext. 36005.

Consent to Participate

I agree to participate in this study, based on the information presented above. I have read the information-consent letter, and I have had the opportunity to receive any additional information that I sought regarding this study. I understand that I may withdraw consent at any time, by informing the researcher, without any penalty. I understand that I may contact the investigators involved with the study if I have any questions. I am aware that this study has been reviewed and received clearance through the Office of Research Ethics, and I am aware that I may contact Dr. Susan Sykes (ssykes@uwaterloo.ca; ext. 36005) if I have any questions or concerns regarding my participation in this study.

Please print your name:____

Signature:____Date:_________________

Witness:____

Signature:____Date:_________________

Information and Consent Letter (Control Condition)

Title: Intentions and Physical Activity Behaviour

Investigators:

Student Investigator: Chris Zehr (czehr@uwaterloo.ca, 519-888-4567 ext. 38180)

Faculty Supervisor: Dr. Peter Hall (pahall@uwaterloo.ca, 519-888-4567 ext. 38110)

You have been invited to participate in a research project assessing how cognitive processes influence physical activity behaviour. The investigation is composed of one in-laboratory session and four smaller sessions delivered over the telephone.

In the laboratory session of this study, your waist circumference will be measured. To do this, using your fingers, you will locate where the top of your hip bone is. You will then place a flexible measuring tape evenly around your body at this level and provide the reading to the researcher. You will then be asked to complete a number of questionnaires pertaining to demographics and intentions, attitudes, and personal behaviour regarding physical activity. Moreover, you will be asked to form a reading goal action plan for the future.

You will also be asked to complete three computer tasks that assess cognitive ability. The first computer task will ask you to press a button when a lower case letter is presented on the screen and refrain from pressing the button when an upper case letter is presented. The second computer task will sequentially present words that belong in different categories. You will then be asked to try to remember the last word presented from each category. In the final computer task you will be shown a number-letter pair in one of four square spaces. When the number-letter pair is presented in the lower two squares, you will be asked to specify whether the letter is a vowel or a consonant by pressing the appropriate button. Similarly, when the number-letter pair is presented in the upper two squares, you will be asked to indicate whether the number was odd or even

Before you leave, you will be fitted with an accelerometer with a strap around your hip that will measure physical activity levels that we ask that you wear for the next seven days except during sleep and when you are in contact with water.

The laboratory session will be followed by four weekly follow-up sessions where you will be asked again to report your exercise behaviour by telephone. As well, we ask that you return the accelerometer to the laboratory after the seventh day of wearing it.

The total time commitment for the study is 2 hours (1 hour for the initial laboratory session, and four 15 minute follow-up sessions). Participants may benefit from gaining knowledge regarding how behavioural health research is performed as well as learning about psychological determinants of health. If you have been advised by your physician not to take part in physical activity or have a health condition that limits your involvement in physical activity, then you should not participate in this study.

For participation in the study, you will receive a $20 grocery gift card even if you decide to withdraw early from the study. All information acquired for the study will be kept indefinitely in the University of Waterloo Social Neuroscience and Health Lab where only authorized researchers will have access. Any electronic information will be retained on a secure password-protected server. All identifying information will be removed.

Your participation is totally voluntary and you may withdraw your participation from this study or decline from responding to any questions asked with no penalty whatsoever. Please direct any questions you have to the researcher or contact Chris Zehr at 519-888-4567 ext. 38180. This study has been reviewed by, and has received ethics clearance from the Office of Research Ethics at the University of Waterloo. If you have any questions or concerns regarding the study, please contact Dr. Susan Sykes, Director, Office of Research Ethics at ssykes@uwaterloo.ca, 519-888-4567, Ext. 36005.

Consent to Participate

I agree to participate in this study, based on the information presented above. I have read the information-consent letter, and I have had the opportunity to receive any additional information that I sought regarding this study. I understand that I may withdraw consent at any time, by informing the researcher, without any penalty. I understand that I may contact the investigators involved with the study if I have any questions. I am aware that this study has been reviewed and received clearance through the Office of Research Ethics, and I am aware that I may contact Dr. Susan Sykes (ssykes@uwaterloo.ca; ext. 36005) if I have any questions or concerns regarding my participation in this study.

Please print your name:____

Signature:____Date:_________________

Witness:____

Signature:____Date:_________________

Information and Consent Letter (No-treatment Condition)

Title: Intentions and Physical Activity Behaviour

Investigators:

Student Investigator: Chris Zehr (czehr@uwaterloo.ca, 519-888-4567 ext. 38180)

Faculty Supervisor: Dr. Peter Hall (pahall@uwaterloo.ca, 519-888-4567 ext. 38110)

You have been invited to participate in a research project assessing how cognitive processes influence physical activity behaviour. The investigation is composed of one in-laboratory session and four smaller sessions delivered over the telephone.

In the laboratory session of this study, your waist circumference will be measured. To do this, using your fingers, you will locate where the top of your hip bone is. You will then place a flexible measuring tape evenly around your body at this level and provide the reading to the researcher. You will then be asked to complete a number of questionnaires pertaining to demographics and intentions, attitudes, and personal behaviour regarding physical activity.

You will also be asked to complete three computer tasks that assess cognitive ability. The first computer task will ask you to press a button when a lower case letter is presented on the screen and refrain from pressing the button when an upper case letter is presented. The second computer task will sequentially present words that belong in different categories. You will then be asked to try to remember the last word presented from each category. In the final computer task you will be shown a number-letter pair in one of four square spaces. When the number-letter pair is presented in the lower two squares, you will be asked to specify whether the letter is a vowel or a consonant by pressing the appropriate button. Similarly, when the number-letter pair is presented in the upper two squares, you will be asked to indicate whether the number was odd or even

Before you leave, you will be fitted with an accelerometer with a strap around your hip that will measure physical activity levels that we ask that you wear for the next seven days except during sleep and when you are in contact with water.

The laboratory session will be followed by four weekly follow-up sessions where you will be asked again to report your exercise behaviour by telephone. As well, we ask that you return the accelerometer to the laboratory after the seventh day of wearing it.

The total time commitment for the study is 2 hours (1 hour for the initial laboratory session, and four 15 minute follow-up sessions). Participants may benefit from gaining knowledge regarding how behavioural health research is performed as well as learning about psychological determinants of health. If you have been advised by your physician not to take part in physical activity or have a health condition that limits your involvement in physical activity, then you should not participate in this study.

For participation in the study, you will receive a $20 grocery gift card even if you decide to withdraw early from the study. All information acquired for the study will be kept indefinitely in the University of Waterloo Social Neuroscience and Health Lab where only authorized researchers will have access. Any electronic information will be retained on a secure password-protected server. All identifying information will be removed.

For participation in the study, you will be compensated with a $20 grocery gift card. Your participation is totally voluntary and you may withdraw your participation from this study or decline from responding to any questions asked with no penalty whatsoever. Please direct any questions you have to the researcher or contact Chris Zehr at 519-888-4567 ext. 38180. This study has been reviewed by, and has received ethics clearance from the Office of Research Ethics at the University of Waterloo. If you have any questions or concerns regarding the study, please contact Dr. Susan Sykes, Director, Office of Research Ethics at ssykes@uwaterloo.ca, 519-888-4567, Ext. 36005.

Consent to Participate

I agree to participate in this study, based on the information presented above. I have read the information-consent letter, and I have had the opportunity to receive any additional information that I sought regarding this study. I understand that I may withdraw consent at any time, by informing the researcher, without any penalty. I understand that I may contact the investigators involved with the study if I have any questions. I am aware that this study has been reviewed and received clearance through the Office of Research Ethics, and I am aware that I may contact Dr. Susan Sykes (ssykes@uwaterloo.ca; ext. 36005) if I have any questions or concerns regarding my participation in this study.

Please print your name:____

Signature:____Date:_________________

Witness:____

Signature:____Date:_________________

APPENDIX C: Feedback Letter

Feedback Letter

Title: Intentions and Physical Activity Behaviour

Investigators:

Student Investigator: Chris Zehr, (czehr@uwaterloo.ca, 519-888-4567 ext. 38180)

Faculty Supervisor: Dr. Peter Hall (pahall@uwaterloo.ca, 519-888-4567 ext. 38110)

We would like to thank you for your participation in our study. Given that individuals often experience difficulty when attempting to achieve health behaviour goals, the main purpose of this study was to investigate how cognitive ability associated with self-regulation influences physical activity behaviour in older adults. As well, we were interested in examining the effect that forming a brief goal-setting strategy would have on subsequent physical activity behaviour.

To assess this, we employed computer tasks to measure differences in certain cognitive processes thought to be involved in behavioural self-regulation that may be important for successful goal-achievement. The first computer task assessed behavioural inhibition, the second computer task assessed working memory or the ability to keep information in mind, and the final computer task assessed the ability to switch between different tasks. All of these abilities measured by the computer tasks are thought to reflect cognitive ability associated with self-regulation. These measures although useful for research purposes are only informative when large aggregates of scores are combined and as such are not informative as clinical tests.

As well, one third of those who participated in this study were randomly assigned to receive a strategy that is thought to facilitate physical activity goal achievement by specifying when, where, and how the behaviour would be achievement. Another third were randomly assigned to the same strategy but for an activity unrelated to physical activity (reading). Finally, one third were randomly assigned to no goal-setting strategy. We then measured physical activity behaviour over the following four weeks to determine to what extent these cognitive abilities and goal-setting strategies predicted future physical activity behaviour.

The data collected in this project will be maintained securely in a laboratory that only authorized researchers will have access to. After the data collection phase of this project has concluded, we will use the data collected to report on group-level statistics associated with this study within the scientific community (no identifying information will be included). If you have any questions or concerns or are interested in learning about the findings of the project, please contact Chris Zehr (czehr@uwaterloo.ca, 519-888-4567 ext. 38180) or Dr. Peter Hall (pahall@uwaterloo.ca, 519-888-4567 ext. 38110).

This investigation has been reviewed by, and has received ethics clearance from the Office of Research Ethics at the University of Waterloo. If you have any questions or concerns regarding the study, please contact Dr. Susan Sykes, Director, Office of Research Ethics at 519-888-4567, Ext. 36005.

APPENDIX D: Physical Activity and Intention Measures

Physical Activity and Intention Measures

1. During the past week, how much total time did you spend doing vigorous physical activity? Please report the total hours for the past 7 days to the nearest ½ hour:
2. During the past week, how much total time did spend doing moderate physical activity? Please report the total hours for the past 7 days to the nearest ½ hour:
3. During the next week, how much total time do you intend to spend doing vigorous physical activity? Please report the total hours for the next 7 days to the nearest ½ hour:
4. During the next week, how much total time do you intend to spend doing moderate physical activity? Please report the total hours for the next 7 days to the nearest ½ hour:

APPENDIX E: Physical Activity Goal Sheet

Physical Activity Goal Sheet

In the space below, please think about and describe when, where, and how you will achieve your physical activity goals.

Now think of any obstacles that may prevent you from achieving your goals.

What are some ways you may be able to overcome those obstacles?

APPENDIX F: Reading Goal Sheet

Reading Goal Sheet

In the space below, please think about and describe when, where, and how you will achieve your reading goals.

Now think of any obstacles that may prevent you from achieving your goals.

What are some ways you may be able to overcome those obstacles?

APPENDIX G: Theory of Planned Behaviour Measure

1. "Daily physical activity would be…"

Extremely Pleasant	Somewhat Pleasant	Neutral	Somewhat Unpleasant	Extremely Unpleasant

2. "Daily physical activity would be…"

Extremely Bad	Somewhat Bad	Neutral	Somewhat Good	Extremely Good

3. "Daily physical activity would be…"

Extremely boring	Somewhat boring	Neutral	Somewhat fun	Extremely fun

4. "Daily physical activity would be…"

Extremely Satisfying	Somewhat Satisfying	Neutral	Somewhat Satisfying	Extremely Satisfying

5. "Daily physical activity would be…"

Extremely Unappealing	Somewhat Unappealing	Neutral	Somewhat Appealing	Extremely Appealing

6. Do most people who are important to you think you should or should not engage in daily physical activity?

1	2	3	4	5	6	7
Strongly think I should not			Neutral			Strongly think I should

7. How much control do you think you have over whether or not you engage in daily physical activity (from 0%-100%)?

8. To what extent do you intend to engage in physical activity on a daily basis over the next month?

1	2	3	4	5	6	7
Not at all			Moderately			Very Strongly

APPENDIX H: Self-Efficacy Measure

Self-Efficacy Physical Activity Measure

I am confident I can participate in daily physical activity when:

1 2 3 4 5 6 7 8 9 10 11

Not at all Confident Very Confident

I am too tired.

1 2 3 4 5 6 7 8 9 10 11

Not at all Confident Very Confident

I am in a bad mood.

1 2 3 4 5 6 7 8 9 10 11

Not at all Confident Very Confident

I feel I don’t have the time.

1 2 3 4 5 6 7 8 9 10 11

Not at all Confident Very Confident

I am on vacation.

1 2 3 4 5 6 7 8 9 10 11

Not at all Confident Very Confident

It is raining or snowing.

1 2 3 4 5 6 7 8 9 10 11

Not at all Confident Very Confident

APPENDIX I: Null Findings

Null Findings

Behavioural Inhibition

The three-way interaction of intention strength, treatment condition, and GNG reaction time was not significant when predicting 1-month self-reported physical activity (ΔR^2=.041, F(2,94)=.209, p=.812)

When assessing accelerometer-based average activity counts, the main effects of intention (β_{INT}=.168, t=.780, p=.438) and treatment condition (ΔR^2=.005, F(2,84)=.206, p=.814) were not significant. The 2-way interaction of intention and treatment condition (ΔR^2=.030, F(2,81)=1.250, p=.292), and the 3-way interaction of intention, GNG reaction time and treatment condition was also not significant (ΔR^2=.002, F(2,73)=.083, p=.920).

Task-switching

The two-way interaction of intention and NL score on 1-month physical activity was not found to be significant (β_{INTxNL}=.021, t=.593, p=.555). Additionally, the three-way interaction of intention, NL score, and treatment condition was not significant (ΔR^2=.005, F(2,74)=2.135, p=.126).

When predicting accelerometer-based average activity counts, there was no main effect of intention (β_{INT}=.143, t=.608, p=.545) or treatment condition (ΔR^2=.005, F(2,84)=.206, p=.814). There was also no detection of a 2-way interaction of intention and treatment condition (ΔR^2=.030, F(2,81)=1.250, p=.292), intention and NL score (β_{INTxNL}=.020, t=.160, p=.873), or a 3-way interaction of intention, NL score, and treatment condition (ΔR^2=.013, F(2,57)=.431, p=.652).

Working Memory

When examining 1-month physical activity, the two-way interaction of intention and KT score was not significant (β_{INTxKT}=.004, t=.128, p=.899). There was also no three-way interaction of intention, KT score, and treatment condition (ΔR^2=.002, F(2,90)=1.263, p=.288).

Neither intentions (β_{INT}=.087, t=.405, p=.686) nor treatment condition (ΔR^2=.005, F(2,84)=.206, p=.814) predicted accelerometer-based average activity counts. The two-way interactions of intention and treatment condition (ΔR^2=.030, F(2,81)=1.250, p=.292) and intention by KT score (β_{INTxKT}=.028, t=.250, p=.803), and the three-way interaction of intention, KT score, and treatment condition (ΔR^2=.014, F(2,70)=.540, p=.585 were not significant.