Universitat de les Illes Balears

Facultat de Psicologia

Memòria del Treball de Fi de Grau

Determinants of real world executive abilities in healthy older adults

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Any acadèmic 2017-18

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Paraules clau del treball:
Executive functions, anxiety and depression, retirement years, fluid intelligence, healthy older adults.

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Acknowledgements

This work was carried out at the University of Edinburgh, and it would not have been possible without an Erasmus+ traineeship grant (Ref. 2017-1-ES01-KA103-036074). The dissertation is based on the internship conducted under the supervision of Dr. Sarah E. MacPherson during the second academic semester.

Special thanks are due to Prof. Pilar Andrés (University of the Balearic Islands) and Dr. Sarah E. MacPherson (University of Edinburgh), who made this project possible and saw it coming to life. Thanks for your continued assistance and advice. We are also especially grateful to all those who offered their support and encouraging words through this journey: family, friends, Erasmus+ fellows and selfless participants.

Abstract

BACKGROUND: Executive functions (EFs) are one of the most difficult skills to assess and the currently used tools lack consistency. Moreover, most of them evaluate a range of different skills without examining whether they mirror real world abilities. EFs are commonly impaired in aging, yet little do we know regarding the impact that other variables, such as depression, anxiety, fluid intelligence or even years since retirement may have on their performance. OBJECTIVES: As a first step, we examined what determines real world executive performance in healthy older adults, and whether it is biased by the above-mentioned variables. Furthermore, a relationship between traditional and ecologically valid executive tasks was investigated. METHODS: a neuropsychology battery was administered to 39 healthy older adults. The battery included a fluid intelligence task (Advanced Progressive Matrices), an anxiety and depression questionnaire (Hospital Anxiety and Depression Scale) as well as different executive measures, some of them traditional (Victoria Stroop test, letter fluency and Brixton test) and others boasting ecological validity (Multitasking test and Behavioural Assessment of Dysexecutive Syndrome). Lineal stepwise regression analyses and correlations between variables were conducted. RESULTS: No overall correlation was found between the traditional and ecologically valid executive tasks, or between both real-world measures. Retirement years was the only variable predicting Multitasking performance, while anxiety and fluid intelligence were the only predictors of BADS performance. CONCLUSION: Real world executive functioning seems to be determined not only by cognition (fluid intelligence) but also by affective factors (anxiety) and age-related issues (retirement years). However, EFs embrace plenty of structures and functions, therefore a successful executive assessment should entail a range of executive tasks. Those involving different structures and highly related to real world performance should be prioritised.

Introduction

Executive functions (EFs) are high-level cognitive processes crucial for everyday life, responsible for achieving specific goals by coordinating different operations of several processes (Elliott, 2003). They enable individuals to cope with new tasks that require them to formulate a goal, to initiate a plan, to amend it when needed and to choose between different behaviours while interrupting inappropriate ongoing responses (Rabbitt, 1997). Every targeted behaviour relies on the functioning of these processes, mainly located in the prefrontal cortex. Damage to this region may result in dysexecutive syndrome (DES), which is characterised by impaired planning, organisation, judgement, decision-making, intellectual abilities and behavioural disinhibition (Elliott, 2003).

There are several clinical tests proposed as assessing EFs. However, not all of them evaluate the same processes nor are related. Executive assessment is rather complicated since there are no behavioural measures that can exclusively tap the functioning of one executive domain alone (MacPherson, Della Sala, Cox, Girardi, & Iveson, 2015). Moreover, EFs assessment revolves around the application of skills and knowledge in other "content-specific" domains to modulate cognition and behaviour (White, 2004). Results of tests which evaluate a single cognitive function often make it difficult to predict the outcome with robust reliability or validity. This is why most studies assessing EFs tend to use several executive tasks (Norris & Tate, 2000).

In order to remove the influence of unreliability and task impurity typical of executive functions (Rabbitt, 1997), latent variable analysis has been commonly used. In their research, Miyake, Emerson, and Friedman (2000) explored the link between three of the most frequently discussed EFs at the level of latent variables: prepotent response inhibition (inhibition), working memory updating (updating), and task-set shifting (shifting). Miyake et al. (2000) observed that these three EFs were not all targeting the same construct (i.e., showed diversity) but did have something in common (i.e., showed unity), providing a view of the EFs structure. A great deal of studies used subsequently these same EFs, reaching results that supported the general principle of unity and diversity of EFs, and suggesting that there are likely dissociations within them (e.g., inhibition, working memory), as well as other EFs not examined (e.g., fluency).

The unity/diversity framework is not the only model of individual differences in EFs (Friedman & Miyake, 2017). Burgess and Alderman (1990) pointed out that patients with DES are amongst the most difficult to assess because, although the individual components of EFs may be intact, patients may be unable to use them. In addition, their clinical quantification has proven to be highly ambiguous due to two major reasons: the nature of the laboratory setting and the relationship between cognitive skills (White, 2004).

Some of the EFs assessment tools may be considered as traditional tasks, such as the Stroop test (Stroop, 1935), the verbal fluency task (Strauss, Sheerman, & Spreen, 2006) or the Brixton test (Burgess & Shallice, 1997). However, despite being some of the most commonly used tests to measure EFs, they are known for presenting a range of limitations that can mainly be gathered in three. Firstly, several reports have found that patients showing good performance on these tasks in spite of presenting clear symptoms of high disorganisation in daily behaviours (Macuglia, de Almeida, Santos, & Giacomoni, 2016). These tests have been claimed to miss executive components involved in real-world situations (Frisch, Förstl, Legler, Schöpe, & Goebel, 2012), giving rise to a considerable concern that casts doubt on whether accuracy and adequacy of these instruments is related to everyday life, meaning a lack of ecological validity on traditional executive tasks.

Secondly, there is a concern that executive tasks are contaminated by fluid intelligence. Some authors argue that individual differences in intelligence rely on executive abilities, identifying fluid intelligence and executive functioning as measures with much in common (Rabbitt, 1997). Fluid intelligence embodies the ability to think logically and work out problems in the absence of task-specific knowledge or experience, predicting real world outcomes (Kievit et al., 2014). It has been observed that frontal patients who showed disorganisation, impulsivity, bizarre behaviour and failure returning to their previous employment exhibited preserved IQ, but tests of fluid intelligence revealed substantial impairment (Duncan, Burgess, & Emslie, 1995), suggesting not only a close link between frontal regions and EFs but also with fluid intelligence. This evidence is supported by other findings, such as a specific set of frontal and parietal activations during fluid intelligence test performance (Roca et al., 2010). A positive correlation was also found between EFs and fluid intelligence, begging the question of how well executive deficits are explained by a fluid intelligence loss (Friedman & Miyake, 2017; Roca et al., 2010).

Finally, traditional tasks are not always sensitive to frontal lesions. Shallice and Burgess (1993) reported three cases of patients who had suffered frontal damage and all of them showed no impairment on a variety of traditional tests despite the presence of remarkable impairments in everyday life. A neuropsychological assessment that only includes traditional frontal executive measures may conclude that a patient performs within normal limits even though her/his relatives continuously complain that s/he performs poorly on everyday tasks involving social processing or multitasking (MacPherson et al., 2015).

Traditional executive tasks have constantly been criticised, among others, for not being specific enough and developing poor representative real-world models. Not to mention that none of these measures have proven to be specific when it comes to assessing executive impairment. However, we may not forget that these tests have broadly been used with the aim of detecting potential executive impairments, instead of identifying the potential degree of deficit resulting from executive dysfunction (García-Molina, Tirapu-Ustárroz, & Roig-Rovira, 2007).

In order to overcome these limitations, another kind of executive task with recognised ecological validity has been developed. Ecological validity refers to the relationship between an individual's performance in real world settings (Sbordone, 1996). It is compounded by two different concepts: veridicality, referring to the prognostic relations between test scores and phenomena in the real environment, and verisimilitude, referring to the extent to which the test demands reflect the skills and tasks required in real environments (Franzen & Wilhelm, 1996).

Therefore, we find two different kinds of EFs measures: traditional and ecologically valid (mirroring real-world executive abilities). More recently, some authors aimed to detect real world executive impairments by developing different ecologically valid tasks or batteries. Two of these tools are the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996) and the Multitasking test (Law et al., 2004).

The BADS is a battery especially designed to predict everyday problems arising from a possible DES, with a predictive overall score for emotion, cognition and behaviour. Though it was mainly devised to assess brain injured patients, it enables clinicians to detect subtle difficulties in organisation and planning among all kind of patients, especially in those who appear to be cognitively well preserved and functioning well in structured situations (Wilson et al., 1996). This tool was developed following two different theorical models: the working memory model, including the presence of a central executive (CE), and the supervisory attentional system model (Norman & Shallice, 1986), responsible for attention. In their research, Norris and Tate (2000) showed that not only its ecological validity was significantly greater than in the traditional tests, but it was also capable of distinguishing between neurological and non-brain damaged groups with an overall success of 74%.

Real-world complex situations require organisation and goal-related behaviour. Some prototypical situations of this kind (such as cooking a meal) are those involving multitasking. Multitasking pools different features happening in every-day situations: delaying intentions, interruptions and unexpected outcomes, many tasks are needed to be completed, interleaving them, and performing one task at a time. In addition, the tasks have differing characteristics, self-determined targets, and no immediate feedback (Burgess, 2000). The key to a successful performance on multitasking relies on the ability to achieve multiple or multi-layered goals (Logie, Law, Trawley, & Nissan, 2010). Burgess, Veitch, Costello, and Shallice (2000) established three different cognitive systems implicated in this process: those underlying retrospective memory elements, prospective memory elements and planning the demands of the activity. For some cases, the most outstanding feature is the failure of prospective memory, translating into the inability to follow time restrictions, keep appointments or meet deadlines (Burgess, 2000). An example of a multitasking test is the Six Elements task from the BADS. It was designed to capture frontal dysfunction not observable on traditional tests and it has proven to be sensitive to age-related cognitive decline, as well as being of clinical relevance (MacPherson et al., 2015).

It has been frequently suggested that cognitive decline in aging is related to a significant decrease of executive functions, resulting in impaired executive performance in older adults (Andrés & Van der Linden, 2000). This impairment is usually followed by a significant deterioration in the yield of daily activities linked to these skills (Monteiro & Peixoto, 2014), nevertheless, how the pattern and course of influence on performance in everyday life still remains unknown (Treitz, Heyder, & Daum, 2007). In their research, Andrés and Van der Linden (2000) found that, besides significantly slower, older adults showed impaired performance during executive tasks such as inhibition.

However, little do we know of the role other variables may play in EFs. For example, an important question is the extent to which people's age of retirement may influence cognition, given that it is one of the most important life transitions in older adults and it implies a major lifestyle change. In a recent paper, Lee, Chi, and Palinkas (2018) showed that retired older adults exhibited significantly lower cognition than those who remained working. What is more, this negative association between retirement and cognition was attenuated by greater engagement in mental activities, highlighting the relevance of both leisure activities and occupation. Yet, there is not only the fact that working has a significant impact on cognition, but also the level of occupational complexity tells, apparently, a great deal. Andel, Finkel, and Pedersen (2016) found that greater complexity of work significantly slowed cognitive aging and it decreased the risk of dementia. Higher levels of occupational complexity were linked to increased intellectual flexibility, better cognitive function, and lower risk of cognitive impairment. As a matter of fact, individuals with higher education, a complex occupation and with several leisure activities showed less cognitive decline and lower risk of dementia.

So far different cognitive aspects that may determine EFs, such as fluid intelligence or aging, have been reviewed, yet we should neither forget nor undermine the impact of other noncognitive factors, such as emotional issues, which may influence the relationship between test performance and everyday performance. Frontal lobes cannot simply be regarded in terms of executive abilities but also in terms of other more emotional and social kind of tasks (MacPherson et al., 2015). Recently, studies regarding the relationship between mood and executive problems have triggered particular interest (Smitherman, Huerkamp, Miller, Houle, & O'Jile, 2007). There are few studies of the relationship between affective disorders and

EFs, most of them are focused on comparisons between specific diagnostic groups, and those examining depressive and anxious symptoms altogether are inconsistent. When it comes to aging, it is known that anxiety and depression are more deeply correlated in older adults and their presence enhances from middle to older adulthood. In addition, age-related decline in cognitive processing plus biased attention due to anxiety or depression could potentially lead to a deterioration in attention and other EFs. Nevertheless, the effect that the milder symptoms of depression and anxiety may have on cognitive functioning in normal aging is still unknown (Beaudreau & O'Hara, 2009). Not many studies have targeted depression symptoms alone with EFs, and fewer are those exploring the relationship between anxiety symptoms alone with EFs. Even though anxiety and depression often appear together, their combined effect on cognitive functioning is rarely considered. Some evidences suggest that comorbid anxiety and depression may have an added impact on EFs deficit, often causing worse outcomes than either alone, including more serious symptoms, higher rates of recurrence, weaker treatment responses and worse psychosocial function (Snyder et al., 2014). Given that there is a lack of data in this field, trying to understand the impact of depression and anxiety on real-world executive performance should become a priority.

The aim of this study was to look at the determinants of real world executive tasks in healthy aging. More specifically, we were especially interested in the role that years since retirement, anxiety, depression and fluid intelligence might play in executive performance. Conversely, we also wanted to examine the degree of relationship between real world and traditional executive tasks. Since it has been argued that these two types of tasks measure different abilities, it was in our interest to explore the presence of a possible dissociation.

To do this, a neuropsychological assessment comprising traditional and ecologically valid executive tasks, as well as anxiety, depression and fluid intelligence measures, were administered to a group of healthy older adults.

Method

Participants

Participants were healthy older adults recruited from the University of Edinburgh's volunteers panel. All of them resided in Edinburgh and decided voluntarily to participate in the present study after reading the information sheet (Annex A). They did not receive any compensation for their time. This study was approved by the PPLS Research Ethics Committee of the University of Edinburgh (Annex B).

Exclusion criteria included (Annex C): colour-blindness, abnormal general cognitive functioning (as measured by MOCA test (*M* = 29.03; *SD* = 1.48)), uncorrected hearing loss or visual impairment, current help for alcohol or drug dependence, or assistance due to memory or thinking problems, any condition that would prevent arm movement and/or the use of both hands, a history of head injury resulting in hospitalisation for more than 24 hours, anti-anxiety, anti-psychotic or antidepressant current intake, and medical or psychiatric conditions that could potentially affect cognitive functioning (e.g. epilepsy, stroke). Owing to non-compliance of one of these, six participants who initially were willing to participate were excluded from the study.

The final sample comprised 39 participants aged between 60 and 84 (*Mean* = 70.41; *SD* = 6.55), from which 23 were females (59%; see Figure 1). Two were left handed (5.1%). Number of completed years of formal education ranged from 10 to 23 years (*M* = 17; *SD* = 3.183) and years since retirement ranged from 0 to 25 (*M* = 8.97; *SD* = 6.97; see Figure 2).

Figure 1:
Gender prevalence

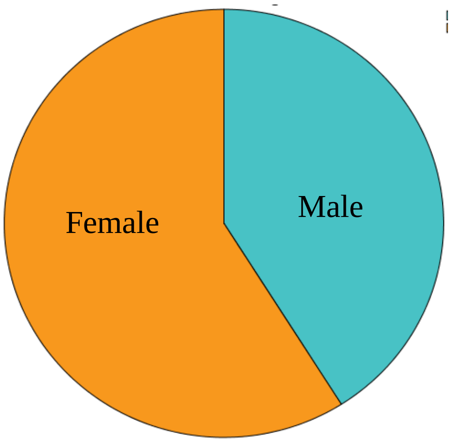
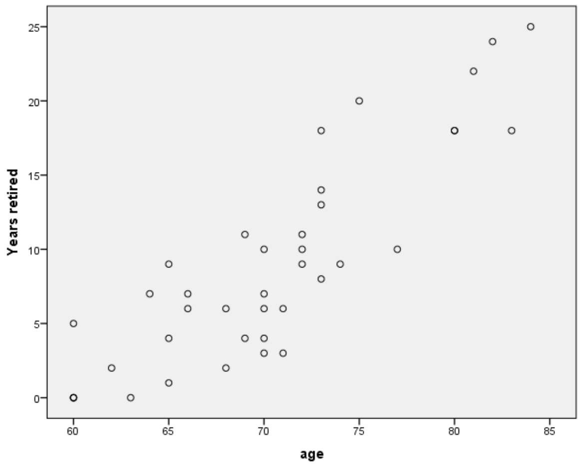


Figure 2:
Retirement years and age scatter plot



Instruments

1. Montreal cognitive assessment (MoCA)

The MoCA (Nasreddine et al., 2005) is a highly sensitive tool detecting cognitive impairment and it was used to ensure that participants' general cognitive functioning was not impaired. It is a thirty-point test administered in ten minutes that evaluates: short-term memory recall, with two learning trials of five nouns and a delayed recall; visuospatial abilities, with a clock and a cube drawing; executive functions, with a shorter version of Trail Making B task, phonemic fluency and a verbal abstraction task; attention, concentration and working memory are assessed with a target detection task using tapping, a subtraction task and a digits forward and backward task; language, naming three low-familiar animals (lion, camel, rhinoceros), repeating two complex sentences and with the verbal fluency task above-mentioned; and orientation to time and space.

2. The Multitasking test

The multitasking test (Law et al., 2004) was a modified non-standardised version of the Greenwich test (Burgess et al., 2000), a multitasking measure where participants were required to attempt, in ten minutes, three open-ended tasks (bead task, tangled lines task and construction task). The multitasking test comprises four different subtasks and participants had to attempt to complete at least part of each subtask over a ten-minute period. A key aspect of this task is that red stimuli are worth extra points, and therefore participants had to bear in mind to pay special attention to these stimuli.

2.1. Telephone subtask

A telephone directory and a list of twenty names were given to participants, five of these names were red coloured and participants had to look for the telephone number matching the names given. Names could be looked for in any order.

2.2. Brick construction subtask

Participants were shown a Lego square tower (8cm x 8cm x 12.5cm) with a central hollow that they had to replicate. The tower had thirteen layers and each one was coloured differently, three of which were red. A box with sufficient bricks to replicate the tower shape was available. Points were given for each layer completed.

2.3. Envelopes subtask

Participants had to place as many sheets as possible in the envelopes provided. There were three different coloured sheets (blue, yellow and red) and there could only be one sheet folded into thirds per envelope. Papers could be selected in any order.

2.4. Beads subtask

A piece of a string with beads threaded was provided as an example and participants had to replicate the beads pattern in an empty string. The pattern comprised twenty-six coloured sections and each section was made up of two beads. Four of these sections were red. Participants had a box with sufficient beads to copy the example.

3. Behavioural Assessment of Dysexecutive Syndrome (BADS)

The BADS (Wilson et al., 1996) is a test battery aimed at predicting everyday problems emerging from Dysexecutive Syndrome. This battery assesses executive functions along six subtests and one questionnaire.

3.1. Rule shift cards test

Using a 21 playing cards booklet, participants' ability to shift from one rule to another and to keep track of the colour of the previous card and the current rule are assessed. According to the first rule, participants are instructed to say "yes" to a red card and "no" to a black one, whereas according to the second rule, they are asked to say "yes" if the card just turned over is the same colour as the previous one and "no" if it is different.

3.2. Action program test

Requiring five steps to its solution, in this subtest participants have to solve how to get a small cork out of a thin transparent tub using a large transparent beaker full of water with a removable lid with a central hole in it, a metal rod L-shaped and a small screw top container with its top unscrewed beside it. Any of these objects can be used to achieve the goal, however, they cannot neither lift up the stand, tub or beaker nor touch the lid with their fingers. Participants must work out that the key to the problem is to use the water to make the cork float.

3.3. Key search test

A drawn square is presented on paper as a field where participants lost their keys. The purpose is to trace, starting from a dot below the square, the route they would follow to make absolutely certain they would find their keys. This task shows the participants' ability to plan an effective and efficient course of action and to monitor their own performance.

3.4. Temporal judgement test

Four short questions concerning commonplace events which take from a few seconds to several years comprise this subtest (e.g. how long do most dogs live for?). Participants are asked to make a sensible guess to answer them.

3.5. Zoo map test

In the first trial participants are required to show how they would visit six listed locations on a zoo map. Nevertheless, when planning the route some rules must be followed: starting at the entrance and finishing in the picnic area and using specific paths only once. To minimise the errors, participants must plan in advance the order in which the locations will be visited. In the second trial, rules remain the same but this time instructions to visit the different places correctly are given to follow.

3.6. Modified six elements test

Instructions to do three tasks (dictation, arithmetic solving and picture naming) divided into two parts (A and B) are given. Participants are required, in ten minutes, to attempt at least something from each of the six subtasks, however, there is a rule they must follow: they are not allowed to do the two parts of the same task consecutively. In this subtest it is not important how well participants perform on each task but how well they organise themselves (whether the rule was broken, the number of subtasks attempted, and the amount of time spent on any task).

3.7. The dysexecutive questionnaire (DEX): self-rating version

Participants are asked to answer this five-point scale twenty-item questionnaire regarding a range of problems commonly associated with DES. It samples four areas of likely changes: emotional or personality, motivational, behavioural and cognitive changes. This questionnaire is independent from the rest of the subtests and it is not necessary to get an overall score.

4. The Brixton Spatial Anticipation Test

The Brixton test (Burgess & Shallice, 1997) is a fifty-six page stimulus book. Each page has the same basic design with ten enumerated circles (two rows of five) and one of them is always blue coloured. The position of this filled circle moves from page to page according to different patterns that come and go without warning. In each page, participants are asked where they think the coloured one is going to be next, based on what they have seen on previous pages. It is an attainment task that measures a person's ability to detect, follow and switch a rule.

5. Advanced Progressive Matrices (APM): Set I

The APM (Raven, Raven, & Court, 1998) set I is a fluid intelligence assessment tool comprising a 12 short items booklet. Each item follows different patterns with the bottom right missing and participants are asked to tell which piece among eight shown below completes the pattern.

6. The Victoria Stroop Test (VST)

The Stroop test evaluates the ease with which someone can keep a goal in mind and inhibit the common response in favour of a less familiar one (Strauss et al., 2006). The VST is a modified version of the Stroop test, it has twenty-four items on three different conditions (naming dots (D), neutral words (W) and words of colour (C) printed in contrasting colours) and the aim is to name as quickly as possible the colour of these dots or words printed in blue, yellow, green or red. An interference effect happens on the third task, when participants must name a colour different from the written one (e.g. "blue" written in red ink). The interference index is calculated by subtracting W from C and dividing it by the sum of W and C.

7. The Hospital Anxiety and Depression Scale (HADS).

The HADS (Zigmond & Snaith, 1983) is a brief self-assessment scale compound of eight items for anxiety and eight for depression, assessing its severity in a five-point scale. Participants had to select the option that most accurately described their feelings in the past week. Total scores are given for anxiety and depression separately.

Procedure

Assessment sessions started by obtaining informed consent (Annex D) and demographic information from participants. They then completed the test battery in about 1 to 1.5 hours. Tasks were administered in the following order: MoCA, Multitasking test, BADS, Brixton test, APM, VST, HADS, and DEX questionnaire. The testing was carried out in the Neuropsychology lab at the University of Edinburgh.

Results

Statistical analyses were conducted using IBM SPSS Statistics, version 22. The threshold for statistical significance was set to $p < .05$. Lineal stepwise regression analyses were carried out to test whether years of retirement, anxiety, depression and fluid intelligence predicted participants' performance on the real world executive tasks (BADS and multitasking separately). Since there are no age adjusted scores for the Multitasking test, statistical analyses were carried out using the standardised BADS score, instead of the age corrected standardised score, thus, a more equivalent scoring method for both groups would be ensured. The results revealed that years since retirement was the only variable explaining variance (18.5%) in multitasking performance ($R^2 = .185$, F (1, 37) = 8.405, $p < .01$), and it was the only significant predictor of multitasking achievement ($\beta = -.43$, $p < .01$). The regression analysis on the BADS revealed that anxiety explained 10.1% of performance ($R^2 = .101$, $F(1, 37) = 4.15$, $p < .05$), and it significantly predicted it ($\beta = -.342$, $p < .05$). The inclusion of fluid intelligence produced an important F-change ($\Delta R^2 = .113$, $F\text{-}change = 5.21$, $p < .05$), and it also contributed to explain BADS performance ($\beta = .338$, $p < .05$).

Correlations were then conducted to investigate the relationship between performance on real world executive tasks and performance on more traditional executive tasks, namely, Brixton test, the Victoria Stroop test and letter fluency. As shown in Table 1, only one correlation between a traditional and an ecologically valid task (the Brixton and the Multitasking test) was significant ($r = .388$, $p < .05$).

Finally, we were interested in the possible correlation between the two ecologically valid executive tasks, and despite not being statistically correlated (Figure 3), there was a trend towards significance ($r = .273$, $p < .1$).

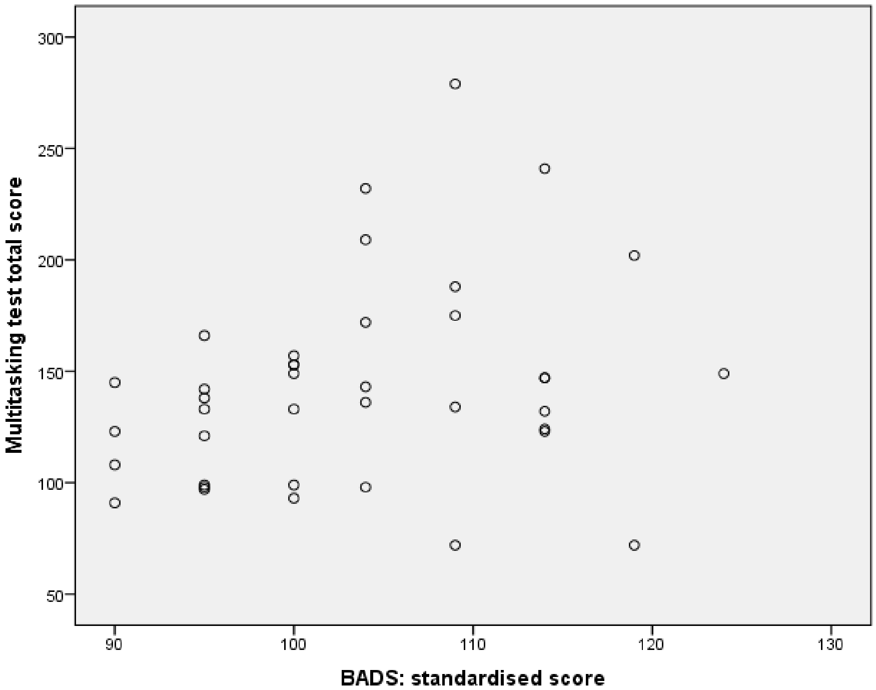
Table 1
Correlations

	1	2	3	4	5
1. Letter F fluency		-.18	.43*	.30	.17
2. Stroop Interference			-.29	-.21	-.17
3. Brixton test				.20	.39*
4. BADS					.27
5. Multitasking test					

*, $p < .05$ (two-tailed)

Figure 3

Multitasking and BADS score scatter plot



Discussion

The aim of this study was to investigate the determinants of real world executive abilities in healthy older adults. We were first interested in the role played by age of retirement, a variable that has received little attention but has recently been suggested as a crucial factor on cognitive aging (Lee et al., 2018). Secondly, we were also interested in clinical aspects, such as anxiety and depression, as they are likely to be present in aging (Beaudreau & O'Hara, 2009). Thirdly, as there is evidence of a relationship between executive functions and fluid intelligence (Rabbitt, 1997), we wanted to know to what extent real world EFs could be determined by it. Finally, it was in our interest to explore the degree of relationship between real world and traditional executive tasks.

Once analysed all the data collected, what caught most our attention was the absence of relationship between both ecologically valid measures. What is more, the results revealed that our two real world executive tasks were differently determined. While multitasking was only determined by years of retirement, BADS performance was predicted by anxiety and fluid intelligence.

Results indicated that retirement years was the only variable explaining multitasking performance. These results are consistent with recent research (Andel et al., 2016; Lee et al., 2018) where it was showed that occupation was related to better late-life cognitive outcomes. Multitasking activities require of the organisation and structuring of goal-related behaviours commonly manifested in real-world situations, making it a complex ability where its success relies on the performance of different cognitive skills. Occupation seems to provide the necessary stimuli to challenge people and make them struggle to keep their performance up. The lack of this challenge in later years gives rise to a significant decline in multitasking abilities, leading to a poorer performance in common real-world situations involving any kind of activity where different cognitive skills are engaged, such as cooking a meal. That is the reason why some authors (Andel et al., 2016; Lee et al., 2018) remark the importance of cognitive and physical leisure activities in cognitive aging during post-retirement, given that continuous use or practice of cognitive skills in activities may help to maintain cognitive performance in later life. Activities such as reading, walking and visiting friends should be fostered during post-retirement. In addition, a progressive retirement in later years would be more suitable so as to enable older adults to better adjust to a new lifestyle and to decrease the steep halt of cognitive occupational engagement.

Conversely, BADS score has shown to be related with two different measures: anxiety and fluid intelligence. The BADS has proven to be an effective tool when it comes to assessing problems arising in daily activities due to DES. This measure focuses on evaluating different skills involved in EFs. However, despite not assessing affective factors, our results showed that it was also sensitive to anxious symptoms since anxiety predicted BADS performance. Our finding fits with other papers proving a relationship between anxiety and EFs. Different studies have shown a link between anxiety and the three different components of EFs (inhibition, updating, shifting) proposed by Friedman and Miyake (2017). Beaudreau and O'Hara (2009) found that anxiety symptoms were associated with poorer inhibition and slower processing speed. Besides that, Warren (2013) showed that shifting was involved in the relationship between worry and elevated anxiety, as well as rumination, an anxiety feature, was related to an impairment in updating. Moreover, their results indicated that anxious arousal was associated with deficits in all three EFs components. However, another explanation to the relationship between anxiety and EFs can be found in the attentional bias characteristic of anxiety. Anxiety diverts attention to internal or external threat, narrowing down attentional resources to perform a task and interfering with attentional control on tasks requiring inhibition, shifting and updating (Beaudreau & O'Hara, 2009). Preoccupation with threat plus age-related decline in cognitive processing could potentially lead to reductions in attention and other EFs (Beaudreau & O'Hara, 2009), as well as higher levels of worry may head to limited cognitive control (Warren, 2013).

Our data also suggests that BADS performance was also explained by fluid intelligence. Fluid intelligence seems to be more involved in real world demands, as it has proven to be more predictive of real world performance than other intelligence measures, such as IQ (Duncan et al., 1995; Roca et al., 2010). In their research, Friedman and Miyake (2017) stated a relationship between fluid intelligence and the three components of EFs (inhibition, updating and shifting). This relationship, however, was only shown in our study with the BADS, as we found no evidence of a link between fluid intelligence with neither the multitasking test nor the traditional executive tasks. One possible explanation to this could be found in BADS reliability. The BADS is a battery assessing different EFs skills, therefore it is more sensitive to mirror real-world abilities as well as possible influences on daily performance. A task only assessing one executive feature (as inhibition in the Stroop) does not provide the necessary data to establish a possible relationship between cognitive functions (such as fluid intelligence) and all the structures and processes involved in real-world executive functioning. This assumption could also be generalised to the prediction of anxiety over BADS performance despite the lack of relationship between anxiety and the other EFs measures.

A striking finding was the utter absence of a relationship between depression and any of the executive measures. Neither real-world nor traditional executive tasks performance was explained by depression, suggesting that EFs are not influenced by depressive symptoms. As Smitherman et al. (2007) reported, the literature encompasses inconsistent findings when it comes to EFs and depression. White (2004) showed an association between depression and problems with attention, memory and problem-solving. Moreover, it was found that anhedonic depression was related to deficits in inhibition and shifting, and it predicted deficits in updating. In accordance with that, Snyder et al. (2014) showed that individuals with depressive disorders had impaired active maintenance of goal-related tasks and working memory. Nevertheless, we may not forget that our results reflect mild depressive symptoms characteristic of global population, in opposition to more severe symptoms found in syndromes or diseases described in literature. All things considered, our results may agree with what Snyder et al. (2014) eventually suggested, that anxiety and depression could affect differently specific neural mechanisms associated with individual EFs processes. This would explain why depression outcomes did not predict executive performance, in contrast to a significant explanation of anxiety over BADS performance.

A point worth bearing in mind is that our analyses did not reveal a correlation between the two core real-world executive tasks. Although it could be argued that it might be related to the size of our sample, it is worth nothing that our analysis clearly shows that they are determined by different factors (multitasking by years since retirement, and BADS by anxiety and fluid intelligence). The dissociations found relate to the structure that has previously been described in the EFs literature, where there may be some overlap or unity between them despite implying different processes (diversity) (Friedman & Miyake, 2017). Both tasks could be measuring different structures and processes. This would explain why they are related to different variables. In addition, both measures boast being ecologically valid, however, their administration and the assessed functions are not the same (the BADS comprises six different tasks and it takes longer to administer). In this sense, we could consider the BADS as a more complete tool since it evaluates EFs in different domains. Be that as it may, we cannot rule the multitasking test out as it has proven as well to reflect the engaged abilities in real world executive performance (Burgess et al., 2000). Furthermore, Burgess (2000) showed that failure at different stages of the Greenwich test (from which the multitasking test stems) was associated with damage to different regions, highlighting the clinical relevance that this kind of tasks may have. The underlying ecological validity in both tasks could explain not their relationship but the slight trend towards significance our results showed between the BADS and the multitasking test.

Another surprising finding was the fact that there was only one significant positive relationship between a traditional and a real-world executive task, namely between the Brixton and the multitasking test. The rest of the traditional tasks lacked any relationship with the real-world tasks. This could once again be explained by the unity/diversity framework of EFs (Friedman & Miyake, 2017), given that multitasking and Brixton performance engage related processes and structures (i.e. both tasks require shifting to some extent).

Conversely, a positive link was found between the Brixton test and the letter fluency task (both traditional executive measures). However, a single relationship involving letter fluency has little significance. As Burgess (2000) showed, multitasking performance might dissociate from verbal fluency performance. Claiming that successful verbal fluency performance could not be taken as evidence of unimpaired multitasking abilities. This would suggest that verbal fluency tasks might be biased, therefore no correlation regarding verbal fluency performance should be taken alone as a strong evidence (Rabbitt, 1997).

Finally, it would be interesting to point out the failure of the DEX predicting executive outcomes in our older sample. Despite the fact that participants were healthy older adults with no apparent altered insight, their answers to the questionnaire did not relate to their own executive performance on any of the executive tasks. This finding agrees with Piquard, Derouesné, Meininger and Lacomblez's (2010) results, who, in spite of administering both DEX questionnaires (self-rating and independent rater versions, instead of only the self-rating version as we did) they came across the same outcome: a lack of a significative relationship between the DEX and the BADS among healthy older adults, making the point that DEX revolves around a global assessment of EFs and behaviour instead of being a specific DES measure.

Before concluding, several study limitations should be mentioned. The first one concerns the lack of normative data in the multitasking test. The absence of standardisation and age-adjusted scoring led to not correcting by age the other, indeed standardised, real-world executive measure (the BADS) in order to ensure that both scoring measures would be as alike as possible. Second, the anxiety and depression questionnaire only included eight items to assess each construct. Not to mention the data were collected from a self-assessment questionnaire, which may undermine the reported anxiety and depression levels. As results show, our sample included participants with a range of different scores on both clinical measures, but maybe a more thorough examination would have enabled a more accurate picture of their affective state and higher accuracy when classifying borderline scores. Third, the DEX questionnaire was only administered to the participants (self-rating). The independent rater version might have afforded a more comprehensive insight into a participant's daily executive functioning. Fourth, as participants were recruited from the University volunteers' panel, some of them recognised having previously passed typical tests such as the Stroop, the letter fluency task or a similar version of the Advanced Progressive Matrices (APM; a fluid intelligence measure). This could be regarded as a drawback since executive and intelligence measures should pursue novelty in order to tap goal identification and strategic planning. As a matter of fact, although the content of individual items of APM may be novel, the format is not, the same with the verbal fluency tasks (Rabbitt, 1997). Lastly, the sample was composed of enrolled volunteers from the University of Edinburgh. All of them had overcome more than ten years of formal education, according to Scottish law, and most of them had higher-level occupations (e.g., teachers, civil servants). Not to mention all of them were contacted through their email account and proved to be competent internet users. These facts may not entirely narrow down the Scottish older population, not even reflect foreign older populations as educational and occupational backgrounds may determine cognitive functions (Lee et al., 2018), as well as culture and local legislation.

Future studies should further explore the impact that retirement years may have on post-retirement cognition and quality of life. Additionally, a more thorough research regarding the effects of mild depressive and anxious symptoms on EFs is needed to overcome the current inconsistent findings. Last but not least, it is noticeable that EFs involve plenty of yet unknown processes and future research should focus on exploring executive structures in order to develop ultimate executive assessing tools and enable the establishment of several ecologically valid EFs tasks.

Conclusion

This study indicated that retirement years was the only variable explaining multitasking performance; whilst anxiety and fluid intelligence were the only predictors of BADS performance. Therefore, years of retirement, anxiety and fluid intelligence seem to be at some extent determinants of real world executive functions.

Despite differing in the relationships and skills assessed, both the multitasking test and the BADS are known to be more reliable predictors of real-world executive abilities than traditional executive tasks, as literature suggests. In fact, none of the traditional executive measures did significantly relate to any of the four variables studied (retirement years, anxiety, depression and fluid intelligence). None of the traditional executive tasks except the Brixton (which correlated with the multitasking test) showed a relationship with any ecologically valid measure.

All things considered, the assessing of real-world executive functions is a non-solved problem (Piquard et al., 2010), and studies seeking a successful executive assessment should keep combining information from different executive measures: standardised tests with information from behavioural observations, self-report tools, interviews and other assessing measures (MacPherson et al., 2015; Rabbitt, 1997).

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Annexes

Annex A. Information sheet

INFORMATION SHEET

PROJECT TITLE
Real world executive abilities in aging and stroke: influence of fluid intelligence and depression.

INVITATION
You are being asked to take part in a research study on the influence age and other factors can have on the ability to multitasking. I (Esther Oliver) am an undergraduate psychology student at The University of Edinburgh, conducting this research under the supervision of Dr Sarah MacPherson. This research has been approved by the Philosophy, Psychology and Language Sciences Research Ethics Committee (2018).

WHAT WILL HAPPEN
In this study, you will be asked a series of short questions to ascertain demographic information (Gender, Age and Education levels). Following this, you will be asked to complete a multitasking assessment, a questionnaire assessing anxiety and depression levels, as well as other paper and pencils tasks similar to puzzles that assess your intellectual abilities and problem solving.

TIME COMMITMENT
The study typically takes one hour and ten minutes.

PARTICIPANTS' RIGHTS
You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn/destroyed.
You have the right to omit or refuse to answer or respond to any question that is asked of you.
You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you should ask the researcher before the study begins.

BENEFITS AND RISKS

Participation in this study involves completion of some standardised tests. Scores from these tests would not be sufficient basis for clinical decisions or diagnosis, contain substantial margins of error, and is not used for diagnostic purposes in this study. Though it is not possible to provide feedback of individual scores to participants, these scores might hint at health problems that some people would want to discuss with an appropriate health professional.

COST, REIMBURSEMENT AND COMPENSATION

Your participation in this study is voluntary. Participants will not receive any contribution for their time in this study.

CONFIDENTIALITY/ANONYMITY

The data we collect do not contain any personal information about you except your age, education levels and gender. No one will link the data you provided to the identifying information you supplied. Your data will be anonymised so there will be no record that links the data collected from you with any personal data from which you could be identified (e.g., your name, address, email, etc.). Up until the point at which your data has been anonymised, you can decide not to consent to having your data included in further analyses. Once anonymised, the data may be made available to researchers via accessible data repositories and possibly used for novel purposes.

FOR FURTHER INFORMATION

Dr Sarah MacPherson will be glad to answer your questions about this study at any time. You may contact her via email at: sarah.macpherson@ed.ac.uk. Alternatively, you may also contact her by telephone on: 0131 650 9862.

If you want to find out about the final results of this study, you should contact me on s1797227@.ed.ac.uk, detailing your involvement in the study.

Once the data has been analysed and the final results are evident I will again be in touch to inform you of these.

If you have questions about your rights in this research, or you have any other questions, concerns, suggestions, or complaints that you do not feel can be addressed by the researcher, please contact the Convener of the PPLS Research Ethics committee (psych.ethics@ed.ac.uk).

Annex B. Ethics Approval

PPLS RESEARCH ETHICS COMMITTEE
SCHOOL of PHILOSOPHY, PSYCHOLOGY and LANGUAGE SCIENCES
The University of Edinburgh
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22 March 2018

Ethics proposal 248-1718/2, entitled Real world executive abilities in aging and stroke: influence of fluid intelligence and depression and submitted by Ester Oliver Cazorla, Dr Sarah E MacPherson, Cait McSweeney and Linda Gibson has been approved by the PPLS Research Ethics Committee per the Department's ethics regulations.

The following files were uploaded with the application:

Filename: 2. INFORMATION SHEET.pdf
Date: 09 Mar 2018 05:51 PM
Purpose: Information Sheet

Filename: 3. CONSENT FORM.pdf
Date: 09 Mar 2018 05:52 PM
Purpose: Consent Sheet

Filename: 3. Email invitation.pdf
Date: 09 Mar 2018 05:52 PM
Purpose: Other

Annex C. Exclusion criteria

EXCLUSION CRITERIA

PLEASE LET THE EXPERIMENTER KNOW IF ANY OF THE FOLLOWING APPLY. YOU DO <u>NOT</u> HAVE TO STATE WHICH ONE.

- **Colour-blindness**
- **Uncorrected hearing loss**
- **Uncorrected visual impairment**
- **Current treatment for alcohol or drug dependence**
- **Seeing a doctor or other professional for memory problems or problems with thinking**
- **A condition that would prevent arm movement and/or the use of both hands**
- **Head injury resulting in hospitalisation for more than 24 hours**
- **Currently taking antidepressant, anti-anxiety, or anti-psychotic medication**
- **Medical or psychiatric condition that could potentially affect cognitive functioning, such as:**
    - **Stroke**
    - **ECT (electric shock treatment)**
    - **Epilepsy**
    - **Brain surgery**
    - **Encephalitis**
    - **Meningitis**
    - **Multiple sclerosis**
    - **Parkinson's disease**
    - **Huntington's chorea**
    - **Alzheimer's dementia**
    - **Schizophrenia**
    - **Bipolar disorder**

Annex D. Consent form

CONSENT FORM

REAL WORLD EXECUTIVE ABILITIES IN AGING AND STROKE: INFLUENCE OF FLUID INTELLIGENCE AND DEPRESSION.

By signing below, you are agreeing that: (1) you have read and understood the Participant Information Sheet, (2) questions about your participation in this study have been answered satisfactorily, (3) you are aware of the potential risks (if any), (4) you are taking part in this research study voluntarily (without coercion), and (5) anonymised data only may be shared in public research repositories.

____

Participant's Name (Printed)*

___________________________________ ___________________________________

Participant's signature* Date

________________________________ _________________________________

Ester Oliver Cazorla Signature of person obtaining consent

**Participants wishing to preserve some degree of anonymity may use their initials (from the British Psychological Society Guidelines for Minimal Standards of Ethical Approval in Psychological Research).*

I am aware that participation in this study involves completion of some standardised tests. I understand that these assessments are not sufficient for diagnostic purposes, nor will they be used in this manner in this study. I also understand that the researchers cannot inform participants of individual test scores, but in the event that I produce scores of potential clinical concern, researchers should (check one and provide relevant contact information):

______Contact me at:____

______Contact my GP at:______________________________________

______Do nothing. I absolve the researchers of any obligation to contact me about this.