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# A systematic review of cognitive failures in daily life: healthy populations

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## Publication Details

Carrigan, N. & Barkus, E. (2016). A systematic review of cognitive failures in daily life: healthy populations. *Neuroscience and Biobehavioral Reviews*, 63 29-42.

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## **Abstract**

Cognitive failures are minor errors in thinking reported by clinical and non-clinical individuals during everyday life. It is not yet clear how subjectively-reported cognitive failures relate to objective neuropsychological ability. We aimed to consolidate the definition of cognitive failures, outline evidence for the relationship with objective cognition, and develop a unified model of factors that increase cognitive failures. We conducted a systematic review of cognitive failures, identifying 45 articles according to the PRISMA statement. Failures were defined as reflecting proneness to errors in 'real world' planned thought and action. Vulnerability to failures was not consistently associated with objective cognitive performance. A range of stable and variable factors were linked to increased risk of cognitive failures. We conclude that cognitive failures measure real world cognitive capacity rather than pure 'unchallenged' ability. Momentary state may interact with predisposing trait factors to increase the likelihood of failures occurring. Inclusion of self-reported cognitive failures in objective cognitive research will increase the translational relevance of ability into more ecologically valid aspects of real world functioning.

## **Keywords**

failures, review, daily, life, healthy, populations, cognitive, systematic

## **Disciplines**

Education | Social and Behavioral Sciences

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## Accepted Manuscript

Title: A systematic review of cognitive failures in daily life:  
healthy populations

Author: Nicole Carrigan Emma Barkus

PII: S0149-7634(15)30073-7  
DOI: <http://dx.doi.org/doi:10.1016/j.neubiorev.2016.01.010>  
Reference: NBR 2342



To appear in:

Received date: 6-7-2015  
Revised date: 20-1-2016  
Accepted date: 26-1-2016

Please cite this article as: Carrigan, Nicole, Barkus, Emma, A systematic review of cognitive failures in daily life: healthy populations. *Neuroscience and Biobehavioral Reviews* <http://dx.doi.org/10.1016/j.neubiorev.2016.01.010>

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# **A systematic review of cognitive failures in daily life: healthy populations**

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## Highlights

- We systematically review everyday cognitive failures in healthy samples.
- Subjective failures are not consistently related to objective cognitive outcomes.
- Failures are shaped by a range of trait- and state-like factors.
- Failures reflect fluctuations in cognitive capacity rather than pure ability.
- Failures tell us about ‘real life’ cognition, distinct to performance in the lab.

## Abstract

Cognitive failures are minor errors in thinking reported by clinical and non-clinical individuals during everyday life. It is not yet clear how subjectively-reported cognitive failures relate to objective neuropsychological ability. We aimed to consolidate the definition of cognitive failures, outline evidence for the relationship with objective cognition, and develop a unified model of factors that increase cognitive failures. We conducted a systematic review of cognitive failures, identifying 45 articles according to the PRISMA statement. Failures were defined as reflecting proneness to errors in ‘real world’ planned thought and action. Vulnerability to failures was not consistently associated with objective cognitive performance. A range of stable and variable factors were linked to increased risk of cognitive failures. We conclude that cognitive failures measure real world cognitive capacity rather than pure ‘unchallenged’ ability. Momentary state may interact with predisposing trait factors to increase the likelihood of failures occurring. Inclusion of self-reported cognitive failures in objective cognitive research will increase the translational relevance of ability into more ecologically valid aspects of real world functioning.

Keywords: Cognitive failures; cognitive failures questionnaire; subjective cognition; everyday cognition; everyday functioning.

## 1. Introduction

Apparently healthy people experience the frustration (and sometimes embarrassment) of ‘brain farts’ or cognitive failures on a daily basis. Common incidents include walking to a room only to forget what you were looking for, locking your keys in the car, or repeatedly pushing an apparently jammed door before noticing the large ‘Pull’ sign emblazoned on its front. Whilst irritating and generally quite minor, some individuals tend to experience these slips more often than others. For these people, cognitive failures can represent a serious concern and barrier to successfully carrying out routine responsibilities. Currently, the factors that increase proneness to cognitive failures are not well understood, and comparisons with objective cognitive domains have done little to assist researchers in determining how such errors might be prevented.

The ageing population is bringing to the fore our limited understanding of cognitive failures. Even healthy ageing appears to be associated with decline in specific types of cognitive functions, such as those involving the demand for recall (Hohman, Beason-Held, Lamar, & Resnick, 2011; Rast, Zimprich, Van Boxtel, & Jolles, 2009). However, increased awareness of dementia means middle-aged and older people are experiencing more anxiety about normal cognitive decline, a phenomenon known as ‘dementia worry’ (Kessler, Bowen, Baer, Froelich, & Wahl, 2012). They are increasingly turning to commercial brain training programs to improve function. The marketplace for these cognitive training tools is projected to be worth US\$5,721.2 million by 2018 (Markets and Markets, 2014). Whilst training in a specific task may improve performance on that task, it is unclear whether improvement

generalises to real life cognitive functioning (Kelly, Loughrey, Lawlor, & Robertson, 2014; Valenzuela & Sachdev, 2009). Available tools target specific aspects of cognitive ability, but do not address everyday problems. Understanding the nature and triggers of cognitive failures, as well as their relationship to formal cognitive assessment, would help improve identification of individuals at risk for normal age-related cognitive decline, dementia, and some psychological disorders, at different points in the lifespan, prior to substantial reductions in cognition and functioning being realised.

The term ‘cognitive failures’ was coined by Broadbent et al. (1982) to refer to minor slips that cause the normally smooth flow of intended action (physical or mental) to be disrupted. Cognitive failures reflect a global liability towards frequent lapses in cognitive control. Several measures have been developed to assess the degree of liability one possesses to express cognitive failures; those identified in this review are listed in Table 1. The most widely used of these is the Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982), which is also the broadest measure in terms of domains of error assessed. Rather than focusing exclusively on the CFQ, we have decided to include all of the cognitive failures measures in the current review. Whilst other measures may focus on particular types of errors, they each tap into the subjective experience of cognitive failures, which is worthy of consideration here.

A number of concerns have been raised with regards to the validity of subjective measures of cognitive functioning. Some authors suggest self-reports of cognition must match up with performance on objective (laboratory-based) tasks in order to be considered valid (e.g. Herrmann, 1982). Therefore, the current lack of a neat marriage between the CFQ and objective outcomes is a concern for many cognitive researchers. This is linked to other more general concerns about self-reports of cognition, such as the high demand placed on respondents’ memory by requiring recall of specific experiences over a relatively long time period (Myin-Germeys, Delespaul, & Van Os, 2003).

Reservations about subjective experiences of cognition also reflect the traditional approach of cognitive psychology, which focuses solely on objectively assessed ‘trait’ intellect (see Horn, 1972). This is known to be predicted by several relatively stable factors; most notably genetics (Davies et al., 2011). Changes in performance occur only in response to biological processes such as ageing, injury, and disease, and produce specific, well-documented cognitive profiles (e.g. González-Blanch et al., 2007; Hildebrandt, Fink, Kastrup, Haupts, & Eling, 2013). Thus, the stability and predictability of trait cognitive ability makes it appealing to clinicians and researchers alike. However, most people feel instinctively that their cognitive functioning varies with their mood, environment, and particularly over time - some days they simply do not function as efficiently as usual, whilst at other times they are far more focused. The objective cognitive tasks, considered the gold standard in both research and clinical settings, whilst useful, capture cognition in an idealistic environment, and at only one point in time. On the other hand, reports of cognitive failures could add to our understanding of how cognitive processes play out in real life, improving ecological validity of research into human cognition.

### ***1.1 Review objectives***

Despite the potential for a better understanding of cognition in real-life contexts, subjectively-reported cognitive slips and failures comprise a small research area. The aim of this review is to identify and draw together the various different factors involved in day-to-day patterns of failures in healthy individuals. Three core questions will be:

- 1) How do we define the construct of cognitive failures?
- 2) What is the relationship between subjectively-reported cognitive failures and performance on objective tasks?

- 3) What biological, psychological and environmental factors influence levels of cognitive failures?

As yet, no review of the cognitive failures literature exists. Thus, the current systematic review is necessary to facilitate the development of a unified model of factors that influence liability towards cognitive failures in otherwise healthy individuals. This is timely given that this area of study has evolved significantly over the past three decades.

## **2. Method**

We designed and reported this systematic review based on the principles of the PRISMA statement (Liberati et al., 2009).

### ***2.1 Search strategy***

Studies were identified by searching electronic databases and scanning reference lists. PsycINFO (1967-June 2015), Web of Science's Social Sciences Citation Index (1956-June 2015), Scopus (1960- June 2015) and the Cochrane database were searched using the following index items via Boolean search criteria: "cognitive slip\* OR cognitive failure\* OR subjective cogniti\* AND everyday;" "cognitive slip\* OR cognitive failure\* OR subjective cogniti\* AND daily." These search terms were derived from examination of seminal cognitive failure articles. No limits were applied for year of publication or language, but only English-translated papers were accessed. Reference lists of key articles were hand-searched. All types of papers were included in the search. The last search was run on 10<sup>th</sup> June, 2015.

## 2.2 Eligibility criteria

Inclusion and exclusion criteria were outlined prior to the search. Studies were included if they were:

- Published in a refereed journal;
- Identified cognitive failures or subjectively-reported cognitive impairment as one of their primary measures or outcomes; and
- Utilised a quantitative, subjective measure of everyday cognitive functioning.

Studies were excluded if they:

- Sampled from a non-healthy/clinical population (e.g. dementia, disease, psychological disorders);
- Were attempts to validate measures with specific populations (e.g. cultural, language groups) or created for specific populations (e.g. hospitalised elderly people);
- Measured subjectively-reported cognitive performance with too few items (i.e. < 5 items if quantitative);
- Came from non-psychological or health-related research fields (e.g. ergonomics); or
- Studied an intervention (e.g. cognitive remediation, CBT for sleep problems).

Case studies, letters to the editor, and conference abstracts were also excluded.

The researchers screened titles and abstracts of the articles gathered during the search against the exclusion criteria. Selected articles were then read and excluded if they focused on any excluded topic or did not use acceptable subjective measures of cognitive failure (Figure 1).

### **3. Results**

We included 45 articles in the review. The studies varied widely in their research design and grouping of participants. Most of the studies used correlational designs ( $n = 38$ ), and the remainder consisted of experimental ( $n = 4$ ), longitudinal ( $n = 2$ ), and population designs ( $n = 1$ ).

#### ***3.1 Study characteristics***

##### ***3.1.1 Location***

A large portion of the studies were led by researchers based in the United States ( $n = 16$ ). This was followed by the United Kingdom ( $n = 9$ ), the Netherlands ( $n = 4$ ), Canada ( $n = 4$ ), Germany ( $n = 3$ ), Ireland ( $n = 2$ ), Italy ( $n = 2$ ), the Czech Republic ( $n = 1$ ), Denmark ( $n = 1$ ), Iceland ( $n = 1$ ), Japan ( $n = 1$ ), and Switzerland ( $n = 1$ ).

##### ***3.1.2 Study populations***

All the articles in this review drew samples from non-clinical populations, including:

- Student populations.
- Organisation personnel, including hospitals and the military.
- Community groups.

##### ***3.1.3 Measures of cognitive failures***

Four different structured self-report measures of cognitive failures were identified in this review. A brief overview of each of these is provided in Table 1. In addition to these, several authors chose to construct their own brief self-report measures of cognitive failures.

This included six articles in which the authors utilised experience sampling methodology to capture cognitive failures in the flow of everyday life by requiring participants to report them either as they were experienced, or at regular intervals throughout the day (Jónsdóttir, Adólfssdóttir, Cortez, Gunnarsdóttir, & Gústafsdóttir, 2007; Kane et al., 2007; Lange & Süß, 2014; McVay, Kane, & Kwapil, 2009; Unsworth, Brewer, & Spillers, 2012; Unsworth, 2015).

The studies are arranged in tables according to the area they explored or compared. Some articles contained overlaps of topics; these were grouped according to their primary focus.

### ***3.2 What are the key features of the construct of cognitive failures?***

#### ***3.2.1 Dimensions of cognitive failures***

Several studies examined the construct of cognitive failures ( $n = 9$ ; Table 2). Cognitive failures were broadly defined as one's tendency to experience errors and slips in functioning (Boomsma, 1998; Broadbent et al., 1982; Wallace, Kass, & Stanny, 2002). The original Broadbent et al. (1982) paper treated cognitive failures as reflecting a trait usefully dichotomised into 'high' and 'low' groups. However, some authors highlighted that alongside this general component, the measure contains more specific factors (Unsworth et al., 2012). To this end, three studies examined the underlying structure of the CFQ via factor analysis. The models produced ranged inclusion of three (Broadbent et al., 1982), four (Wallace et al., 2002) and five factors (Pollina, Greene, Tunick, & Puckett, 1992). All articles highlighted memory and action slips as core dimensions measured by the CFQ, whilst perception, distractibility, and interpersonal intelligence were less consistently identified.

CFQ scores were found to be distributed normally throughout the healthy population, although women tend to report more failures than men (Boomsma, 1998; Kanai, Dong,

Bahrami, & Rees, 2011). A large-scale genetic study of Dutch families suggested that 50% of variability in scores is due to familial heritability (Boomsma, 1998). The authors of the study found no evidence for effects of shared environment; it was suggested that non-genetic variance in CFQ scores is shaped by external factors specific to the individual rather than the family unit.

Exploring further the biological component of cognitive failures, two MRI studies reported that increased parietal grey matter was predictive of greater distractibility in everyday life (Kanai et al., 2011; Sandberg et al., 2014). One of these groups also found that reduced GABA in the occipital lobe was associated with increased risk of cognitive failures (Sandberg et al., 2014). Both findings were thought to be indicative of the role of organic deficits in everyday processing efficiency. High neural density may be a sign of inadequate synaptic pruning during development (Kanai et al., 2011); low GABA levels may limit the ability to selectively suppress sensory information (Sandberg et al., 2014). Together, GABA levels and parietal grey matter volume explained about 50% of interindividual variation in failures (Sandberg et al., 2014). This supports a possible neural basis for the heritability of cognitive failures.

### ***3.2.2 Real world performance***

The broad purpose of gauging subjective measures of cognition is to gain insight into ‘real life’ cognitive functioning, beyond that contrived in the lab or the doctor’s office. Accordingly, cognitive failures have been found to correlate with spousal ratings of performance, indicating that at least some failures are observable behaviours (Broadbent et al., 1982). They also correlate moderately with academic outcomes assessed by the Scholastic Aptitude Test (SAT) in the U.S. (Unsworth et al., 2012). Further, positive correlations between the incidence of at-fault traffic accidents and self-reported cognitive failures (Larson & Merritt, 1991) illustrate

the unique ability of self-report to predict important (indeed, potentially life-or-death) performance outcomes in real life.

Conversely, cognitive failures do not correlate with standard tests of intelligence (Broadbent et al., 1982; Larson & Merritt, 1991). Larson & Merritt (1991) proposed that cognitive failures are a qualitative feature of attention management style, and as such do not tap into the intentional, effortful processes that are engaged in IQ testing. Several researchers held the view that the CFQ accesses aspects of cognition distinct to the processes tapped by traditional assessment methods.

### ***3.2.3 Relationship with stress***

In one of few studies involving repeated measurement, Broadbent et al.'s (1982) findings suggested that predisposition towards cognitive failures increases susceptibility to minor mental health symptoms following a period of exposure to stress – in this case, nurses placed on more stressful wards. In Broadbent et al.'s (1986) later research, they further posited slips reflect a preferred (albeit problematic) processing strategy more likely to be employed by high CFQ-scorers in states of high anxiety. That is, when not anxious, high CFQ-scorers may be able to perform just as well as their low scoring counterparts. This perhaps suggests that there are individual differences (i.e. trait-like factors) which predispose some individuals to experiencing cognitive failures when exposed to stress; this would in turn exacerbate the negative impacts of stress.

Contrary to this, a week-long experience sampling study found no link between perceived stress levels and number of slips experienced as reported in vivo (Jónsdóttir et al., 2007). Of course, perceived stress captures only one component of stress; namely an individual's perception of their control over factors in their life, as well as persistent background stress. It

is possible more affective and acute measures of stress will be more closely associated with cognitive failures in the flow of everyday life. There are two studies which provide evidence to support this conjecture. First, negative mood states exacerbated cognitive failures in daily life for those who reported high levels of mind-wandering in the lab (McVay et al., 2009). Secondly, cognitive failures of individuals with good control capacity were more likely to be increased when faced with distracting environmental factors (e.g. chaos, unpleasant tasks), whereas those with poor objective control experienced failures regardless of context (Kane et al., 2007). It may be that the CFQ is most useful in examining stress-triggered variations in performance, rather than stable neurological deficits (Mahoney, Dalby, & King, 1998).

### ***3.3 What is the relationship of cognitive failures to performance on objective cognitive tasks?***

Several papers selected for this review investigated the relationship between cognitive failures and objectively assessed cognitive domains ( $n = 11$ ; Table 3). Cognitive domains were studied via performance on lab-based tasks, and included attentional networks, behavioural inhibition, and working memory and executive control (e.g. Berggren, Hutton, & Derakshan, 2011; Broadbent et al., 1986; Ishigami & Klein, 2009). Whilst performance outcomes in each of these domains were associated with self-reports of cognitive failures (e.g. Berggren et al., 2011; Ishigami & Klein, 2009; McVay et al., 2009; Tipper & Baylis, 1987), findings were inconsistent and no definitive link between failures and a specific objective assessment is yet evident.

#### ***3.3.1 Attention***

Seven articles focused on the relationship between different aspects of attention and everyday slips (Broadbent et al., 1986; Forster & Lavie, 2007; Ishigami & Klein, 2009; Tipper

& Baylis, 1987), with mixed findings. An early paper reported that failures did not correlate with any measure of attention, however higher CFQ scores were associated with a relative performance advantage on a search task compared to a focused attention task (Broadbent et al., 1986). Subsequent studies generally found that high distractibility on lab tasks was moderately correlated with more frequent cognitive failures (Forster & Lavie, 2007; Ishigami & Klein, 2009; Murphy & Dalton, 2014; Tipper & Baylis, 1987). Individuals with higher cognitive failures demonstrated longer reaction times than those with lower scores, in both the presence of distractors alongside an absence of negative priming (Tipper & Baylis, 1987), and under conditions of low perceptual load (Forster & Lavie, 2007). They were also more susceptible to auditory distractors (Murphy & Dalton, 2014). To be distracted is to allow irrelevant information to interfere with performance of a current activity (Bergman, O'Brien, Osgood, & Cornblatt, 1995); it therefore seems likely that attentional abilities would influence frequency of slips in our busy, distraction-laden way of life.

Of note were two linked experience sampling papers by Unsworth et al. (2012; 2015). These compared objective cognition with number of failures reported during everyday life over the course of a week. The initial study found that attentional control performance was correlated with reports of failures (Unsworth et al., 2012). However, the later extension of the analysis identified a relationship between intraindividual variations in attentional control (as indicated by shifts in reaction times from trial to trial) and daily slips (Unsworth, 2015). This supports the existence of a state-like component of cognitive failures concurrent to its trait-like elements, and accentuates the need to consider how best to make use of comparisons between existing objective assessments and failures.

### ***3.3.2 Inhibition***

The domain of inhibition encapsulates the ability to suppress actions that interfere with goal-driven behaviour (Aron, 2007). This objective domain also varied in its relationship with cognitive failures. Considering behavioural inhibition first, there were no differences between high and low cognitive failure groups on performance of a visual Go/NoGo task (Roche, Garavan, Foxe, & O'Mara, 2005). On a physiological level, however, those who report more frequent cognitive failures demonstrated increased latency of antisaccade in an eye-movement inhibition task, suggestive of both poorer inhibition and greater distractibility (Berggren et al., 2011). Additionally, when completing a Go/NoGo task, individuals with higher cognitive failures demonstrated larger and earlier N2 and P3 components; event-related brain potentials thought to reflect activity of the cortical inhibition system (Roche et al., 2005). That is, participants with more cognitive failures have to work harder on a cortical level to inhibit their behavioural responses under challenging conditions. Taken together, these studies suggest while there may be no objective differences in behavioural inhibition in those prone to cognitive failures, they may possess a global cortical inefficiency in the physiological mechanisms which underpin behavioural and perceptual inhibitory responses.

### ***3.3.3 Working memory and executive control***

Working memory is defined as the ability to concurrently store and manipulate information (Baddeley, 2010), whilst executive control organises and maintains actions and thoughts according to goals (Kiefer, 2012). Working memory and executive control tasks are often grouped together since control of attention and resource allocation is essential in supporting working memory (Lara & Wallis, 2014). Like attention and inhibition, working memory and executive control are thought to be essential to our ability to process relevant

information and stay “on track” to successfully carry out daily activities. Objective working memory capacity and lapses in executive control (indicated by task-unrelated thoughts), whilst completing laboratory-based tasks, were both found to be associated with cognitive failures (Kane et al., 2007; McVay et al., 2009). However, one study found that this association only held true for certain levels of cognitive load; participants with high working memory ability actually reported more failures when faced with less challenging tasks (Kane et al., 2007). This might link to the popularly-held lay view that boredom triggers mind-wandering, thereby increasing the chance of mistakes. Overall, correlations between cognitive failures and working memory and executive control were not consistently identified.

### ***3.4 What non-cognitive factors influence cognitive failures?***

#### ***3.4.1 Personality and functioning***

Thirteen papers looked at the relationship between personality, functioning, and the CFQ (Table 4). Higher cognitive failures were found to be related to negative affect (Payne & Schnapp, 2014), neuroticism (Wilhelm, Witthöft, & Schipolowski, 2010) and trait anxiety (Mahoney et al., 1998), whilst hypomania was associated with lower scores (Rodriguez et al., 2013). Cognitive failures were proposed to be one of multiple phenomena seen in people with these particular personality traits, and self-awareness was considered to be significant in the interpretation of these findings. An example hypothesis was that neuroticism may lead to increased reporting of cognitive failures since inappropriate worries result in inflated reports of problems (the “complaint hypothesis;” Wilhelm et al., 2010) . On the basis of this, it was proposed that measures of cognitive failures are contaminated by variability introduced via self-awareness deficits (e.g. Chan et al. 2011; Rodriguez et al., 2013; Wilhelm et al., 2010).

#### *3.4.1.1 Dissociative experiences*

Three papers focused specifically on exploration of how tendency towards dissociative experiences may relate to cognitive failures. The interest in this particular personality factor was based on obvious similarities between sub-clinical dissociative experiences such as derealisation (e.g. daydreaming) and mind-wandering aspects of cognitive failures. A strong positive correlation between dissociative experiences and cognitive failures was robustly and consistently found across all studies (Bruce et al., 2007; Merckelbach, Muris, & Rassin, 1999; Wright & Osborne, 2005). Both of these constructs were viewed as aspects of personality (Wright & Osborne, 2005) that reflect an underlying vulnerability to lapses in cognitive control (Merckelbach et al., 1999) and subsequent difficulties integrating information and processes as usual (Bruce et al., 2007; Wright & Osborne, 2005). A related finding was that individuals who experience more involuntary autobiographical memories tend to have higher CFQ scores (Kamiya, 2014). Whilst the constructs are distinct, these types of involuntary memories may be linked to the more disruptive intrusive memories experienced in post-traumatic stress disorder. The intrusions in Kamiya's study were recorded whilst participants were walking without attending to anything in particular; it may be that those prone to mind-wandering experience fluctuations in cognitive failures in response to situations of reduced attentional demand.

#### *3.4.1.2 Schizotypy*

Five articles examined the association between cognitive failures and schizotypy, a normally distributed personality structure reflecting hypothetical risk for psychosis (Van Os & Kapur, 2009). Whilst some "high schizotypes" may develop a psychotic disorder, the majority will not (Kaymaz, et al., 2012). As such, schizotypy has been included in this review as a

dimension of healthy personality similar to the others included here which all have links through to some clinical end point. All authors found a positive correlation between schizotypy and cognitive failures, and it was suggested that subjectively-reported cognitive complaints may represent an endophenotype of risk for schizophrenia (Corcoran, Devan, Durrant, & Liddle, 2012; Laws, Patel, & Tyson, 2008). Further, Pfeifer et al.'s (2009) longitudinal study identified higher cognitive failures as a predictor of later negative schizotypal symptoms (e.g. introversion, social anhedonia). Cognitive failures may: a) contribute to the development and maintenance of schizotypal symptoms; or b) coexist with other symptoms, with the two underpinned by related neurological mechanisms.

The debate over the impact of self-awareness on self-reporting was revisited in exploring cognitive failures as a core biomarker of schizotypy. Both Chan et al. (2011) and Laws et al. (2008) found robust correlations between schizotypy and cognitive slips in the absence of objective deficits. These two papers assessed cognitive slippage, which is similar to cognitive failures in that it asks about distractibility and maintenance of goal-directed thinking, but also includes some items identifying distortion of thought more specific to schizotypy (e.g. 'My thoughts are more random than orderly'). One group concluded that self-awareness problems precede other forms of cognitive impairment in psychosis (Chan et al., 2011); the other proposed awareness remains intact prior to illness onset, enabling high schizotypes to monitor subtle problems that go undetected by objective assessments (Laws et al., 2008).

Cognitive failures and schizotypy both have demonstrated heritability (e.g. Boomsma, 1998; Myin-Germeys, Krabbendam, & van Os, 2003). Despite the overlap between the two, there does not seem to be a shared genetic basis. Schizotypy in one family member was not predictive of cognitive failures in another, lending further support to the idea that cognitive failures rely on both inherited traits and individual environmental factors (Pfeifer et al., 2009).

### **3.4.2 Biological**

A portion of articles sought to study biological factors associated with cognitive failures in healthy individuals ( $n = 13$ ; Table 5). Most of these explored circadian rhythm or the healthy ageing process. One article examined cognitive failures in pregnancy (Cutler, Graf, Pawluski, & Galea, 2011). The authors found that whilst laboratory assessments failed to identify any deficits in pregnant versus non-pregnant women, some of their objective ‘field’ tasks (e.g. remembering to call the researchers on a specific day) demonstrated impairments, as did women’s own self-reports of cognitive failures. The influence of depression and physical symptoms such as fatigue on subjectively-reported but not objective cognition was also noted, further highlighting the significance of ecologically valid measures in understanding experience

#### *3.4.2.1 Sleep-wake cycle*

Three articles explored the influence of sleep and the circadian cycle on everyday cognition. Severity of insomnia was reported to be associated with daytime cognitive failures, independent of mood and stress levels (Wilkerson, Boals, & Taylor, 2011). Levels of wakefulness were also considered as an aspect of personality. Wallace et al. (2003) noted that individuals prone to boredom typically experience daytime sleepiness and distractibility, thus, high levels of cognitive failures are likely a natural consequence of their personality. Another study examined individual preferences for morning versus evening hours: individuals known respectively as ‘larks’ and ‘owls’ (Mecacci, Righi, & Rocchetti, 2004). Larks reported variable levels of cognitive failures with a peak in problems in the evening hours, whilst owls experienced their cognitive failures as stable throughout the day. This provides support for the

existence of individual circadian differences that interact with time of day to influence cognition.

#### *3.4.2.2 Age*

Eight articles examined the relationship between cognitive failures and normal ageing. Whilst the CFQ has been used primarily to study young adults, it demonstrates no age-related measurement bias (Rast et al., 2009). Age-related cognitive decline is widely acknowledged as a relatively common phenomenon (Hanninen et al., 1996), but a longitudinal study found that higher failures predicted a steeper-than-usual trajectory of decline in verbal memory function in particular (Hohman et al., 2011). Despite this, there were few differences between the overall number of everyday failures reported by older and younger people (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Lange & Süß, 2014; Reese & Cherry, 2006), and one study found that older people actually reported fewer slips (Mecacci & Righi, 2006).

However, when Rast et al. (2009) analysed CFQ scores using a three-factor model of the measure, they found that people tend to become more forgetful but less distractible with age. They noted a sharp decrease in distractibility occurs in those in their sixties, and proposed this may be due to the substantial reduction in attentional demands that comes with retirement-related lifestyle changes. On the other hand, some authors held that objective performance deficits and poor ratings by informants prove that older people do make more errors in daily life, but are incompetent in monitoring and reporting these (Harty, O'Connell, Hester, & Robertson, 2013; Mecacci & Righi, 2006). In contradiction, an experience sampling study found a moderate correlation between older people's CFQ scores and in vivo reports of slips (Lange & Süß, 2014). This perhaps again highlights potential limitations of the use of objective assessments as a comparison point for perceptions of day-to-day failures. In addition, there

may be factors specific to older people to consider. For example, the advantage of life experience: older people can and do actively compensate for their absent-mindedness by adjusting the cues they use – both internal and external – for memory and attention (Maylor, 1990).

#### **4. Discussion**

In this systematic review, we identified and summarised existing studies of cognitive failures in healthy populations. The topics explored using the CFQ and other subjective measures varied widely. This paper focused on reviewing cognitive failures in healthy population samples, with the aim of identifying key features of cognitive failures and their relationship to objective cognition. We also aimed to develop a model of factors that influence liability towards cognitive failures in otherwise healthy individuals.

##### ***4.1 Limitations***

There are several possible limitations of this review. First, appraisal of studies was difficult due to poor definition clarity for cognitive failures across articles. In addition, the fact that this area of research is still somewhat exploratory (with the bulk of articles describing correlational data) meant that systematic critique of study quality as per the PRISMA statement was not feasible. Perhaps as this field matures more studies using randomised controlled trials and papers meeting the higher quality of PRISMA criteria will eventuate. The majority of studies used the CFQ however measures differed across studies. For instance, one study used qualitative analysis (Jónsdóttir et al., 2007) but focused on the frequency of errors reported, and so was included here. Despite these limitations to our ability to present a systematic review which strictly adheres to the tight recommendations of PRISMA, the articles included have

allowed us to begin to develop a more comprehensive model of cognitive failures, as per the overarching aim of this review.

There did not appear to be a significant publication bias, with articles reporting positive and negative results. Time and access limitations meant that it is likely that not all relevant articles published pre-1990 were accessed; thus, information stemming from earlier trends in the approach to cognitive failures may be limited. However, we are confident that all key papers from this period were included, and as such our picture of the changing understanding of cognitive failures is adequate.

#### ***4.2 Features of the construct of cognitive failures***

Problems with memory and action slips are identified as core dimensions measured by cognitive failures (Broadbent et al., 1982; Pollina et al., 1992; Wallace et al., 2002). However, this tight definition may exclude some aspects of everyday failures such as more general cognitive functioning, distractibility, and mind-wandering. On the basis of the studies gathered here, we suggest a broader definition: cognitive failures reflect errors in real world planned thought and action, proneness to which is determined by internal and external exacerbating factors.

Although the mode of inheritance has not been explored as yet, heritability could be conferred: 1) directly through dominant, recessive, or more likely a number of genes conferring a small effect; 2) indirectly through a general inefficiency of information processing; or 3) indirectly through familial risk for personality variables, which in themselves increase the likelihood of failures occurring. Related to this is the finding that women are more at-risk for slips than men (Boomsma, 1998; Kanai et al., 2011). Again, this may stem from a number of sources including a direct biological basis, or indirectly via personality traits that occur at more

elevated levels and/or more frequently in women and are also associated with cognitive failures. For example, women score higher on neuroticism than men (Costa, Terracciano, & McCrae, 2001; Wilhelm et al., 2010), which may render them more alert to and aware of their own errors. Regardless of the mechanism, the heritability and gender differences of cognitive failures points towards a set of behaviours which are stable and trait-like.

The final core feature of cognitive failures is one that tends to be implied only; they encompass errors that occur in a particular context: “real life.” This assumption needs to be made explicit given that most cognitive research examines cognition that is *not* occurring in ecological contexts. The necessarily subjective approach of cognitive failures highlights that the personal, real-time experience of cognition in an everyday context is both measureable and meaningful, despite being a clear departure from traditional cognition research.

#### ***4.3 Cognitive failures versus objective performance***

The correlations between self-reported cognitive failures and performance on domain-specific neuropsychological tasks are small at best (e.g. Ishigami & Klein, 2009; Wallace et al., 2002). While the search for such a relationship has been the focus of much recent research into cognitive failures, it is interesting to note that multiple studies have compared selective attention with everyday failures, whilst few have explored other cognitive ability domains. Certainly, an attentional deficit would seem to be the most obvious neuropsychological concern – mind-wandering could serve as the catalyst for many of the most common types of failures. However, further research into other subtypes of attention, working memory, and inhibition is perhaps warranted, given the potential significance of each of these in managing multiple and complex demands in daily life. Ignoring these gaps, if we take the criterion for validity of self-reported cognition to be correspondence with objective neuropsychological performance, the

CFQ clearly falls short. However, as stated above, we may not be looking at corresponding constructs in objective neuropsychological performance and subjectively-reported cognitive failures.

Roughly half of the articles reviewed here attribute the gap between objective and subjectively-reported cognition to impairments in the ability to self-monitor (e.g. Chan et al., 2011; Rodriguez et al., 2013; Wilhelm et al., 2010). For example, neuroticism (Wilhelm et al., 2010), stress, and anxiety (Mahoney et al., 1998) are all related to cognitive failures, but may also induce biased styles of responding to questions regarding personal performance. Whilst this explanation is popular in the literature, the theoretical basis is not yet well established. Different authors view CFQ scores that are not predicted by neuropsychological outcomes as indicators of exaggerated (Wilhelm et al., 2010) or alternatively under-developed (Chan et al., 2011; Rodriguez et al., 2013) self-awareness (or insight). The inconsistency in these interpretations may stem from authors adjusting them according to the direction of their expected results compared to those obtained. Recent research utilising experience sampling found that neurotic individuals reported increased failures in vivo, presumably in the absence of biases expected in retrospective self-reports (Lange & Süß, 2014). The debate around the role of self-awareness in cognitive failures is ongoing.

Despite the lack of correlation with neuropsychological outcomes, cognitive failures relate closely to a range of real life outcomes. These include likelihood of being the at-fault driver in a car accident (Larson & Merritt, 1991), university entrance scores (Unsworth et al., 2012), and behavioural observations from spouses (Broadbent et al., 1982). These findings further support the idea that objective and subjective assessments of cognition could represent two different but equally valuable concepts for measurement. The best way to conceptualise this difference is not yet clear. However, a quick glance at the nature of *how* we go about traditional neuropsychological testing (at one time point; in one isolated, idealistic test setting)

would suggest that its correspondence to real world functioning would be poor. In real world cognition multiple factors interlink, combine, and interact, in ways still yet to be investigated, to shape our capacity according to levels of stress, the people around us, or even whether it is 9am or 5.30pm. Again, this gap in our knowledge likely stems from the long-standing focus on ability in human cognition, which has been to the detriment of our understanding of how ability is implemented in the more chaotic setting of daily life.

#### ***4.4 Factors contributing to cognitive failures***

Given that the experience of cognitive failures seems to be distinct from neuropsychological ability, research in this area has gradually turned towards exploring the influence of other aspects of the individual and their daily context. Whilst the definition that arises from the existing literature highlights a possible primary basis in biology (i.e. genetics and sex), a range of secondary factors are also evident. We have grouped these into stable factors and variable factors (see Figure 2).

##### ***4.4.1 Stable factors***

A number of factors that are considered trait-like are associated with increased frequency of cognitive failures (see the blue/inner circles of the model, Figure 2). The strong link with dissociative experiences (Bruce et al., 2007; Merckelbach et al., 1999; Wright & Osborne, 2005) is not surprising; lapses in control that trigger mild dissociation are similar to those resulting in unexpected errors in routine tasks. Schizotypy is also related to more frequent cognitive failures (Giesbrecht et al., 2007; Laws et al., 2008; Pfeifer et al., 2009); this may be through similar mechanisms as there is a documented relationship between schizotypy and dissociation (Barkus, Stirling, & Cavill, 2010). Schizotypy represents the subclinical end of a

spectrum of psychosis-proneness, and failures may represent a subclinical level of the cognitive deficits often seen in schizophrenia. The possible mechanism by which neuroticism (Wilhelm et al., 2010) and trait anxiety (Mahoney et al., 1998) increase the likelihood of cognitive failures in daily life has been discussed earlier, and is less clear. Whilst failures in both schizotypy and dissociation are viewed as reflecting core deficits in cognitive control, neuroticism and anxiety tend to be perceived by researchers as linked to problems of self-awareness.

Alternatively, it is possible that failures represent patterns of cognition that are characteristic of particular personality types. Another possibility is that cognitive failures may contribute to (or even play a causal role in) personality. Taking schizotypy as an example, consistently high rates of cognitive failures could reduce success of social functioning, which is another feature of this personality structure (Miller & Lenzenweger, 2012). We could also interpret personality traits such as anxiety, neuroticism, and schizotypy as more broadly reflecting difficulties in emotional regulation, which determines ultimate sensitivity of cognitive capacity to external stressors. Using another example from schizotypy, an additional load such as stress is needed to trigger problems in objective performance in high schizotypes (Smith & Lenzenweger, 2010), and this would likely be reflected in everyday failures. This remains speculation however, due to the limited research on the relationship between cognitive failures and personality. Nevertheless, the link with several personality traits is strong, and provides further evidence that there is stability in tendency towards failures.

#### ***4.4.2 Variable factors***

Equally as influential in cognitive failures are state-based, variable factors (see the red/outer circles of the model, Figure 2). Those that have been identified in the current review vary widely, and experience would suggest it is likely that many more have yet to be studied.

Most people would agree that their ability to concentrate appears to be reduced in times of high stress, or when they feel fatigued or have low mood. Accordingly, day-to-day cognitive failures seem to increase reliably in response to poor sleep quality and low mood (Payne & Schnapp, 2014; Wilkerson et al., 2011), as well as high anxiety (Mahoney et al., 1998; Mecacci et al., 2004). Also unsurprisingly, the environment and current activity influence failures as well. Challenging tasks or chaotic surrounds can trigger slips (Kane et al., 2007) but so can finding oneself feeling bored (Wallace et al., 2003). Although no studies exist as yet, we could also suspect contextual features such as social setting (and individual expectations associated with this) and task saliency would also impact the flow of cognition.

Hormonal state and age are biological factors which, whilst more stable than emotional or environmental states, also constantly change over time. Anecdotal evidence suggests that hormonal changes can significantly impact on normal cognition. This has been particularly evident in women, with the whole gamut of phases including pre-menstrual states, menstruation, pregnancy and ‘baby brain,’ and menopause interfering with normal cognition in women (e.g. Cuttler et al., 2011; Henry & Rendell, 2007; Keogh, Cavill, Moore, & Eccleston, 2014; Sherwin, 2013). This could be another reason women tend to report more failures: they are regularly exposed to physiological processes that may interrupt functioning either directly, or indirectly through symptoms such as fatigue and lowered mood. However, research examining subjectively-reported failures across the menstrual cycle is yet to be conducted.

Surprisingly, given popular views of ageing, the current review did not provide strong evidence for an age-related increase in cognitive failures. Older people tended not to complain of more problems than younger people (Kramer et al., 1994; Reese & Cherry, 2006) although some researchers did identify problems with specific areas such as memory, but not attention (Rast et al., 2009). Linking back to the self-awareness debate, it is possible that, as some

researchers have suggested, older people are inaccurate in their reporting (Harty et al., 2013). However, it is also possible that older adults hold an advantage in terms of awareness of problems and experience in using compensatory strategies, resulting in the relative parity of young and old CFQ scores (Maylor, 1990). Some researchers have suggested that the lack of an increase in failures with age may be more closely associated with environment (Rast et al., 2009); that is, that the less demanding lifestyle of retirement limits opportunity for mistakes. This conclusion is debateable, as by definition, failures are unexpected errors in the normal flow of daily life, and their occurrence is not dependent on particular types of lifestyle or activities. Overall, the current findings suggest that heightened cognitive failures are not necessarily part of healthy ageing. Further research should seek to determine their utility as an early indicator of where dementia or psychological difficulties may be evolving, particularly given that this can be easily captured with a brief questionnaire.

The final factor identified in this review is time of day. Not only does lack of sleep impact functioning during the day (Wilkerson et al., 2011), but personal preference for the morning or evening hours also shapes the pattern of failures that will occur over the course of the 24-hour circadian cycle (Mecacci et al., 2004). We have placed time in the outer circle of our model of cognitive failures as it is the one factor that will always be exerting influence, no matter what else is in play. Time may seem a superfluous inclusion, however, traditional assessment of cognition generally ignores it and the current findings suggest it is vital to explaining the fluctuations in functioning that we all experience throughout every day. The study of the stress-related hormone cortisol is an example of research that has acknowledged the significance of time of day. There is recognition of a diurnal pattern of cortisol secretion, which is biologically pre-programmed but also responsive to behavioural and environmental stressors (Dmitrieva, Almeida, Dmitrieva, Loken, & Pieper, 2013). As such, the preferred methodology includes sampling cortisol levels at multiple time points over multiple days.

Given the link between stress and cognitive failures, this approach to measurement is likely also of value to cognitive research.

#### ***4.4.3 Co-occurrence and interaction of contributing factors***

Notably absent from our proposed model is underlying cognitive ability. Even very broad measures such as IQ are unable to predict which individuals will experience more or less cognitive failures (Larson & Merritt, 1991). Whilst this is potentially due to the different goals of objective and self-report approaches to cognitive research, the model we suggest here could provide for another explanation: ability may interact with context in which cognition is occurring. This fits with the findings of Kane et al. (2007) that those with low ability experience failures quite consistently, whilst those higher in ability tend to experience slippage only when faced with distracting environments. Despite the ongoing search for a link to neuropsychological performance, we consider that at this stage there is insufficient evidence for us to include cognitive ability in the model. However, the possible interaction of other stable factors with shifts in state is highlighted.

As yet, very few studies have examined whether co-occurrence of factors may have an additive or otherwise impact on the likelihood of experiencing failures. The model proposed here highlights that whilst the various aspects of biology, personality, mood, and environment affecting cognitive failures are distinct, within an individual any combination of these could exert influence at the same time. Visually, the model depicted in *Figure 1* as applied to one person would feature the outer circles constantly shifting around the stable inner ones throughout each moment of the day. The alignment of factors at any given point in time would determine how effectively that person will perform. This interplay is an unavoidable part of human life, but one which is routinely overlooked.

Consideration of the effects of co-occurring factors may also help solve the debate on the problem of self-awareness and bias in reporting. For example, those personalities that have been linked to greater cognitive failures without necessarily exhibiting deficits of ability, such as schizotypal, anxious, or neurotic types, are known to be more reactive to both interpersonal and environmental stress (Collip et al., 2013; Gunthert, Cohen, & Armeli, 1999). It may be that such individuals experience problems whilst dealing with the time-pressures and hassles of daily responsibilities, but *not* when asked to perform in the relative calm of the laboratory. In one similar interaction already elucidated, people with a preference for morning hours (i.e. ‘morning larks’ in circadian typology) are more likely to experience failures in the evening hours (Mecacci et al., 2004). As such, rather than having poor self-awareness, it may be that the occurrence of failures reflects a diathesis-stress-like process.

#### ***4.5 Conclusions and directions for cognitive failures research***

Cognitive researchers have never been quite comfortable with the idea of measuring cognition using anything other than a relatively narrow range of objective assessment paradigms. The subjective way in which measures such as the CFQ gauge problems in everyday functioning is perceived as especially questionable. However, the findings of this review highlight that whilst self-reported failures do not appear to directly reflect any specific domain of ability, they are reliably influenced by a range of other factors. Some of these contributing factors are trait-like and have potential to shape a person’s functioning from birth, whilst many are dependent on momentary shifts in surroundings and time of day. Therefore, concerns about the validity of treating cognitive failures as a measure of cognitive ability are founded. Instead, we propose that the construct of cognitive failures actually provides a measure of cognitive *capacity*. Capacity is understood here as one’s level of cognitive

performance in a particular situation. It is perceived to be fluid; shifting over time and with context. This is distinct from cognitive ability, which is understood as the relatively stable level at which a person may optimally function, given ideal circumstances. Ability is biologically determined (by genetics, age, and disease status), whilst capacity is shaped on a momentary basis and reflects the fluctuations that are observed in performance during real life.

Much of the research into cognitive failures thus far has been disparate in terms of both the construct's conceptualisation and the contributing factors of interest. In addition, no studies thus far have considered the interaction between factors. Our model of cognitive failures as a gauge of cognitive capacity, whilst preliminary, could provide a unitary basis for future research. We suggest the following key goals for further study:

- 1) Elucidate the effects of co-occurring key trait and state factors in cognitive failures, such as trait anxiety and stress.
- 2) Explore the relationship between cognitive failures and psychological disorders.
- 3) In the long-term, determine whether a brief self-report tool such as the CFQ, which could be easily administered by a primary-care clinician, holds potential as an early diagnostic indicator for diseases such as dementia and schizophrenia.
- 4) Also in the long-term, determine whether everyday cognitive failures may serve as a target for early intervention in diseases such as dementia and schizophrenia.

Whilst the 'what' for future research is relatively clear, the 'how' is less so. The existing research makes clear that the full range of fluctuating factors relevant to day-to-day cognitive experiences simply cannot be measured in the lab. The recent emergence of experience sampling methods offers a means of evaluating many of these factors in more ecologically valid ways. If for no other reason, this form of ambulatory assessment is necessary to capture the time of day effects that invariably influence us all. This method requires a great deal of

refinement in its application to cognitive failures, however it may be the next step in the emerging shift in cognitive research from the laboratory to real life. Whatever the method future researchers choose, they will be contributing to an emerging strong field which holds the potential to understand the working of our minds at their most important: during our everyday lives.

### **Acknowledgements**

Dr. Emma Barkus is in receipt of a Young Investigator Award from the Brain and Behaviour Research Foundation (formally NARSAD), and also receives in kind support from GW Pharmaceuticals, UK.

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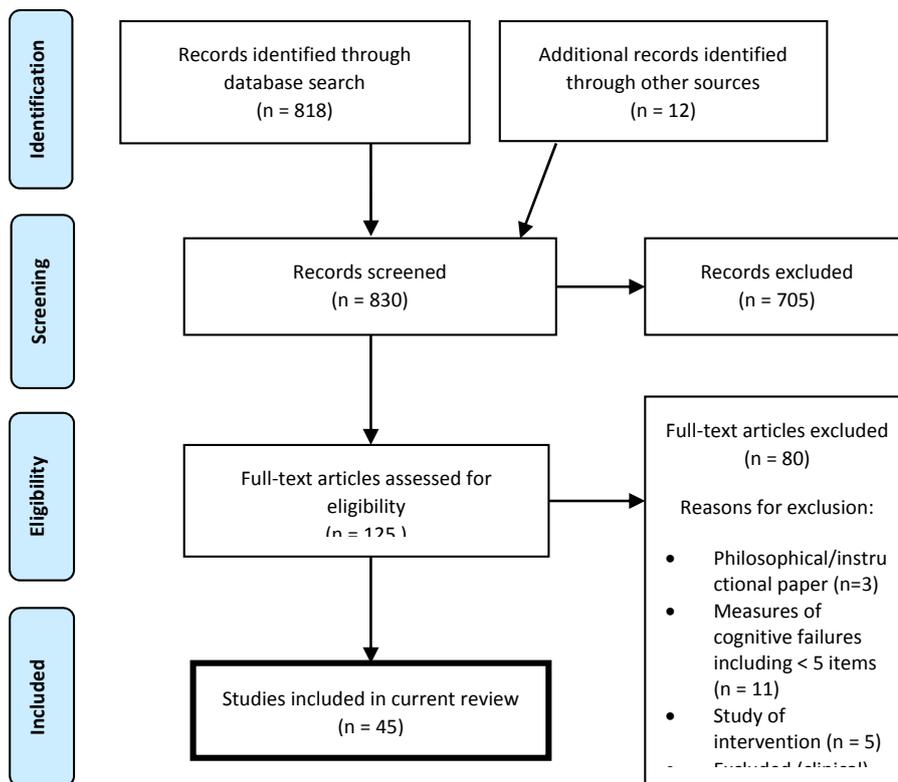
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### **Figure captions**

Figure 1. Flow diagram of study selection for systematic review of published research on cognitive failures in healthy populations.

Figure 2. Factors associated with increased risk of cognitive failures.

Fig 1



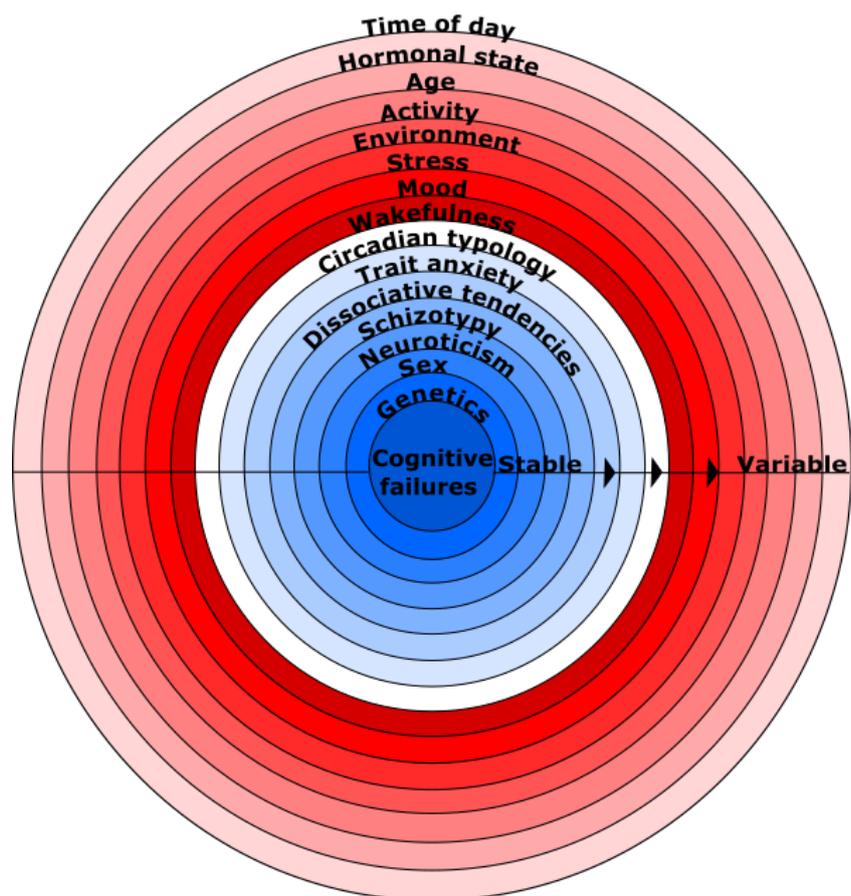


Fig. 2

Table 1. *Self-report Measures of Cognitive Failures in Articles Selected for Review*

Measure	Domains of error assessed	Structure of measure	Sample item
Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982) Self and informant versions available.	- Perception - Memory - Misdirected action	25 items describing common slips of thought and behaviour. Frequency rated along 5-point scale from Very Often to Never.	Do you fail to listen to people's names when you are meeting them?
Cognitive Slippage Scale (CSS; Miers & Raulin, 1987)	- Confused thinking - Speech deficits	35 items designed to measure cognitive slips and distortion. Requires a True/False response.	I often find myself saying something that comes out completely backwards.
Dysexecutive Syndrome Questionnaire (DEX; Burgess, Alderman, Wilson, Evans, & Emslie, 1996)	- Inhibition - Intentionality - Executive memory	20 items describing behaviours arising from problems with executive control. Frequency rated along 5-point scale from Very Often to Never.	I get events mixed up, or get confused about the correct order of events.
Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie, & Maylor, 2000)	- Memory	16 items describing particular types of memory errors. Frequency rated along 5-point scale from Very Often to Never.	Do you decide to do something in a few minutes' time and then forget to do it?

Table 2

Reference	Study sample and population	Findings
Broadbent et al. (1982) <sup>1,2</sup>	910 participants across groups drawn from various healthy populations.	CFQ correlations with existing measures suggest three aspects of cognitive failures being measured: memory, perception, and action. Weak correlations with social desirability and neuroticism scales; no correlation with intelligence.
Larson & Merritt (1991) <sup>1</sup>	159 healthy adult male Navy recruits.	CFQ scores were positively correlated with the number of times young men had been cited for causing a significant traffic accident. Intelligence was not related to accidents or CFQ scores.
Pollina, Greene, Tunick, & Pucket (1992) <sup>1</sup>	419 healthy students.	Principal components analysis identified 5 internally-consistent factors: Distractibility, Misdirected Actions, Spatial/Kinaesthetic Memory, Interpersonal Intelligence, and Memory for Names.
Boomsma (1998) <sup>1</sup>	1651 healthy twin pairs and parents recruited from the community (the Netherlands).	Found the heritability of CFQ scores to be about 50%, with females reporting higher mean CFQ scores in both parent and child generations. There was no association between CFQ scores and education level or age.
Wallace, Kass, & Stanny (2002) <sup>1</sup>	335 healthy students and Navy personnel.	Analysis yielded 4 internally-consistent factors of the CFQ: Memory, Distractibility, Blunders, and (memory for) Names.
Jónsdóttir, Adólfsdóttir, Cortez, Gunnarsdóttir, & Gústafsdóttir (2007) <sup>3</sup>	189 healthy volunteers.	No correlation between perceived stress and number of slips reported over a week in a diary. A weak correlation with pre-diary estimate of functioning was present.

Notes: <sup>1</sup> = CFQ self-report; <sup>2</sup> = CFQ informant-rated, <sup>3</sup> = self-reports captured using experience sampling in vivo.

Kanai, Dong, Bahrami, & Rees (2011) <sup>1</sup>	145 healthy volunteers.	Greater density of grey matter in the left superior parietal lobe predicted CFQ scores; as did performance on an attentional capture task in the lab.
Markett, Montag, Diekmann, & Reuter (2014) <sup>1</sup>	500 healthy adults.	Carriers of C/C genotype of the dopamine receptor D2 were less susceptible to failures, with the genotype explaining about 1.9% of heritability in CFQ scores. The link was partially mediated by trait impulsivity.
Sandberg et al. (2014) <sup>1</sup>	36 healthy adult males.	Increased GABA in the occipital lobe was correlated with decreased CFQ scores, and density of grey matter in the left superior parietal lobe also predicted CFQ scores. Together, variations in occipital GABA and LSPL accounted for 50% of intra-individual variation in failures.

Table 3. *Objective Cognitive Domains And Their Relationship with Cognitive Failures*

Reference	Cognitive domains studied:			
	Selective attention	Alerting attention	Working memory/ Executive function	Inhibition of behaviour
Broadbent, Broadbent, & Jones (Broadbent et al., 1986) <sup>1</sup>	χ	χ	-	-
Tipper & Baylis (1987) <sup>1</sup>	√	-	-	-
Roche, Garavan, Foxe, & O'Mara (2005) <sup>1</sup>	-	-	-	χ
Kane et al. (Kane et al., 2007) <sup>3</sup>	-	-	χ*	-
Forster & Lavie (2007) <sup>1</sup>	χ*	-	-	-
Ishigami & Klein (2009) <sup>1</sup>	√	√	χ	-
McVay et al. (2009) <sup>3</sup>	-	-	√	-
Berggren, Hutton, & Derakshan (2011) <sup>1</sup>	√	-	-	√
Unsworth, Brewer, & Spillers (2012) <sup>3</sup>	√	-	χ	-
Murphy & Dalton (2014) <sup>1</sup>	√	-	-	-
Unsworth (2015) <sup>3</sup>	√	-	√	-

Notes: <sup>1</sup> = CFQ self-report; <sup>3</sup> = self-reports of everyday failures captured in vivo via experience sampling. √ = Significant association, χ = no significant association, - = not examined in the study, \* = relationship was mediated by cognitive demands of the task at hand (i.e. relationship exists only at specific levels of demand).

Table 4

Reference	Study sample and population	Findings
<b><i>Personality and functioning</i></b>		
Mahoney, Dalby, & King (1998) <sup>1,2</sup>	138 healthy adults.	CFQ scores were positively correlated with measures of stress and both trait and state anxiety. CFQ scores of self and others' reports correlated.
Wilhelm, Witthöft, & Schipolowski (2010) <sup>1</sup>	3,122 healthy participants; characteristics unspecified.	Interpretation of combined results of 5 studies indicates that probability of reporting subjective impairment is increased by high neuroticism.
Rodriguez et al. (2013) <sup>1</sup>	128 healthy undergraduate students.	Individuals at high risk for bipolar appraised themselves as more high-functioning than did low-risk individuals. There were no objective differences, and no relationship between CFQ and working memory scores.
Kamiya (Kamiya, 2014) <sup>1</sup>	24 healthy undergraduate students.	The number of autobiographical memories experienced by individuals on a 20 minute walk was moderately positively correlated with CFQ score.
Payne & Schnapp (2014) <sup>1</sup>	129 healthy undergraduate students.	Negative affective states were moderately correlated with overall CFQ scores, whilst positive affect was not.
<b><i>Dissociative experiences</i></b>		
Merckelbach, Muris, & Rassin (1999) <sup>1</sup>	128 healthy undergraduate students.	Significant positive correlations exist between dissociative experiences and reports of cognitive failures. Cognitive failures were not related to fantasy proneness.
Wright & Osborne (2005) <sup>1</sup>	80 healthy undergraduate students.	Strong positive correlation between dissociative experiences and cognitive failures. Cognitive failures were not related to performance on working memory tasks involving secondary interference.
Bruce et al. (2007) <sup>1</sup>	1040 healthy undergraduate students.	Significant correlations between cognitive failures and measures of dissociative experiences.
<b><i>Schizotypy</i></b>		
Giesbrecht, Merckelbach, Kater, & Sluis (2007) <sup>1</sup>	185 healthy undergraduate students.	Two cognitive processes of cognitive failures and fantasy-proneness account for 58% of the link between dissociation and schizotypy.
Laws, Patel, & Tyson (2008) <sup>5</sup>	65 healthy participants.	There were no differences between high and low schizotypes on a battery of executive function tasks. However, high schizotypes did report a greater frequency of everyday executive problems.
Pfeifer, van Os, Hanssen, Delespaul, & Krabbendam (2009) <sup>1</sup>	566 genetically related pairs from the community.	Proneness to cognitive failures was associated with negative/depressive dimensions of schizotypy. Cognitive failures and schizotypy did not share a genetic basis.
Chan et al. (2011) <sup>5</sup>	93 healthy students and community members.	There were no differences between high and low schizotypes on a battery of executive function tasks. However, high schizotypes did report a greater frequency of everyday executive problems. Low schizotypes' subjective reports were related to some objective outcomes.
Corcoran, Devan, Durrant & Liddle (Corcoran et al., 2013) <sup>1,5</sup>	269 healthy students.	Found a strong positive correlation between schizotypy and CFQ and DEX scores.

Notes: <sup>1</sup> = CFQ self-report; <sup>2</sup> = CFQ informant-rated; <sup>5</sup> = DEX

Table 5

Reference	Study sample and population	Findings
Cuttler, Graf, Pawlusi, & Galea (2011) <sup>1,4</sup>	61 pregnant women.	Found subjective impairment but no evidence of objective deficits in pregnant women. Depressed mood and physical symptoms were associated with greater subjective problems.
<i>Sleep-wake cycles</i>		
Wallace, Vodanovich, & Restino (2003) <sup>1</sup>	126 healthy US military personnel and 137 undergraduate students.	Higher daytime sleepiness and proneness to boredom was predictive of everyday failures, and military personnel reported more sleepiness and failures than students.
Mecacci, Righi, & Rocchetti (Mecacci et al., 2004) <sup>1</sup>	390 healthy undergraduate students.	Frequency of reported cognitive slips was increased with neuroticism, anxiety, and extreme morningness (vs. eveningness in circadian typology). Morning types were more susceptible to errors in the evening, whereas evening types were more uniform in their slippage throughout the day.
Wilkerson, Boals & Taylor (2011) <sup>1</sup>	941 healthy undergraduate students.	Found a positive relationship between severity of insomnia and cognitive failures, even after controlling for confounds of depression, stress and anxiety.
<i>Age</i>		
Maylor (1990) <sup>1</sup>	320 female adults between the ages of 52-95.	Regardless of intelligence, individuals with higher CFQ scores were more likely to forget to call researchers in a memory task (i.e. had worse prospective memory). There was no relationship between retrospective and prospective memory performance.
Kramer, Humphrey, Larish, Logan, & Strayer (1994) <sup>1</sup>	30 elderly adults.	No differences between older and younger adults in self-reported failures, but older adults demonstrated slight objective impairment in some aspects of inhibition. CFQ correlated with several outcomes of objective inhibitory tasks.
Mecacci & Righi (2006) <sup>1</sup>	1826 healthy adults aged 16 -85 years.	Older people reported fewer cognitive failures than younger people, and their metacognition (attitudes/worry about cognition, cognitive confidence, etc.) did not seem reduced. However, across age groups, metacognitive worries were associated with increased failures.
Reese & Cherry (2006) <sup>1,6</sup>	96 healthy adults recruited from the community.	Overall CFQ did not differ between older or younger adults, or between those with high or low verbal ability. CFQ scores were not related to objective performance.
Rast, Zimprich, Van Boxtel, & Jolles (2009) <sup>1</sup>	Cross-sectional data from 1303 healthy adults.	The CFQ is free of age-related measurement bias. The factor of forgetfulness increases with age, whilst distractibility suddenly decreases in the mid-60s.
Hohman, Beason-Held, Lamar, & Resnick (2011) <sup>1</sup>	98 adults with mean age 75 followed over mean 11.5 years.	Higher levels of cognitive failures were associated with steeper rates of decline in objective verbal memory performance and increased activity in insular, lingual and cerebellar areas during memory processing.
Harty, O'Connell, Hester, & Robertson (2013) <sup>1</sup>	90 healthy adults aged 18 – 90.	Older people tended to underestimate the frequency of their cognitive failures relative to informant reports. Older people also demonstrated poorer online awareness of their errors in an objective attentional task. There was no relationship between CFQ and objective cognitive performance.
Lange & Stüb (Lange & Stüb, 2014) <sup>1</sup>	91 healthy adults aged 60 – 76 years.	The frequency of failures as collected via experience sampling correlated moderately with the CFQ. Neuroticism was more closely correlated with ES failures than the CFQ. There was no correlation between age and CFQ score.

Notes: <sup>1</sup> = CFQ self-report; <sup>4</sup> = PRMQ; <sup>6</sup> = other quantitative measure of cognitive failures constructed by authors.