Title: Re-evaluating the measurement and influence of conscious movement processing on gait performance in older adults: development of the Gait-Specific Attentional Profile

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Highlights

- The MSRS lacks sensitivity to detect conscious movement processing during gait
- The current study validates the 11-item Gait-Specific Attentional Profile (G-SAP)
- MSRS score is not associated with gait characteristics
- G-SAP CMP subscale predicts gait velocity, step length and double limb support

Abstract

Background. Recent decades have seen increased interest in how anxiety–and associated changes in conscious movement processing (CMP)–can influence the control of balance and gait, particularly in older adults. However, the most prevalent scale used to measure CMP during gait (the Movement-Specific Reinvestment Scale (MSRS)) is generic (i.e., non-gait-specific) and potentially lacks sensitivity in this context.

Methods. In a preliminary study, we first sought to evaluate if MSRS scores associated with the number of CMP-related thoughts self-reported by older adults while walking. The next aim was to develop and validate a new questionnaire (the Gait-Specific Attentional Profile, G-SAP) capable of measuring gait-specific CMP, in addition to other attentional processes purported to influence gait. This scale was validated using responses from 117 (exploratory) and 107 (confirmatory factor analysis) older adults, resulting in an 11-item scale with four sub-scales: CMP, anxiety, fall-related ruminations, and processing inefficiencies. Finally, in a separate cohort of 53 older adults, we evaluated associations between scores from both the G-SAP CMP subscale and the MSRS, and gait outcomes measured using a GAITRite walkway in addition to participants' fall-history.

Results. MSRS scores were not associated with self-reported thoughts categorised as representing CMP. In regression analyses that controlled for functional balance, unlike the MSRS, the G-SAP subscale of CMP significantly predicted several gait characteristics including velocity (*p*=.033), step length (*p*=.032), and double-limb support (*p*=.015).

Significance. The G-SAP provides gait-specific measures of four psychological factors implicated in mediating the control of balance and gait. In particular, unlike the MSRS, the G-SAP subscale of CMP appears sensitive to relevant attentional processes known to influence gait performance. We suggest that the G-SAP offers an opportunity for the research community to further develop understanding of psychological factors impacting gait performance across a range of applied clinical contexts.

Keywords

Anxiety; gait; fear of falling; reinvestment; rumination

Abbreviations

Movement-Specific Reinvestment Scale: MSRS

Gait-Specific Attentional Profile: G-SAP

Conscious movement processing: CMP

Berg Balance Scale: BBS

1. Introduction

Research demonstrates the profound influence that increased fall-related anxiety—and associated changes in attentional focus—can have on postural control and locomotion [1–3]. For example, fall-related anxiety is associated with increased muscular co-contraction and reduced movement in the knees, hips and ankles [4], and slower gait during both clinical assessments [5] and experimental tasks [3,6]. Researchers have proposed that these anxiety-related outcomes may be underpinned by heightened conscious processing of walking movements [2,3,5]. The applied interest in this topic relates largely to older adults or patients with neurological disorders displaying a fear of falling and/or deficits in balance control; factors that are independently associated with increased fall-risk [2,7].

Consciously processing gait can occur in a variety of contexts, particularly when balance is threatened, but also manifests following injury or disease (e.g., Parkinson's or Stroke) [8,9]. This motor control strategy has been shown to directly influence locomotion, resulting in slower, less-efficient (e.g., shorter steps and increased muscular activation) and more unstable patterns of gait [10,11]. Conscious movement processing (CMP) also leads to impaired motor planning [12,13], reduced retention of visual spatial information [9], reduced attentional processing efficiency [8] and greater stepping errors [13]. This evidence is largely accrued from studies experimentally manipulating anxiety and/or attentional focus. However, in apparent contradiction, results from cross-sectional studies provide very little supporting evidence for CMP-related differences [14,15].

One potential explanation for this discrepancy may relate to the measure commonly used to assess a walker's propensity to consciously monitor and/or control their movements: the generic (non-gait-specific) Movement Specific Reinvestment Scale (MSRS) [16]. The MSRS has been instrumental in highlighting how shifts (typically anxiety-related) toward CMP can influence performance in motor tasks; especially in ontogenetic motor skills, such as sporting actions [17]. However, recent work suggests that the way anxious performers engage in CMP may differ considerably in phylogenetic tasks, such as walking [2]. This leads to the suggestion that the MSRS lacks sensitivity to measure CMP during gait-specific tasks and, as a consequence, researchers in this field may have been drawing misleading conclusions from extant literature.

The current study comprised three central aims: i) to scrutinise the MSRS by determining if the nature of self-reported thoughts related to CMP during gait are more evident in older adults reporting high MSRS scores (*MSRS Verbal reports protocol* – Study 1), ii) develop and validate a short (time-efficient) tool—the Gait-Specific Attentional Profile (G-SAP)—capable of reliably measuring self-reported levels of CMP during gait (in addition to other attentional processes purported to influence gait), and iii) evaluate associations between both the MSRS and the CMP subscale of the G-SAP and functional gait performance (*G-SAP validation and evaluation* – Study 2). We predicted a lack of association between MSRS and both self-reported CMP-related thoughts and gait performance. In contrast, we predicted that the CMP sub-scale of the G-SAP would be significantly associated with gait performance.

2. Re-examining the MSRS in the context of gait: Verbal reports protocol

2.1.1 Participants

Twenty one community-dwelling older adults were recruited from local authority housing schemes in West London (mean age = 75.3 ± 7.8 years, mean score on Berg Balance Scale (BBS) [18] = 50/56 ± 3.1, 7/21 reported falling in the previous 12 months).

2.1.2 Protocol and analysis

Participants completed the MSRS as a trait measure [16]. They were then asked to walk at a self-selected pace along an 8m walkway, and step over two raised obstacles (obstacle height above walkway = 23cm, distance between obstacles = 300cm). Participants performed three trials.

During each walk, participants were filmed using a video recorder placed adjacent to the walkway. At the end of the final trial, participants were shown the videos of them walking on a computer screen and were asked to reiterate thoughts that they recalled during the task (if any). All responses were transcribed verbatim and, following a single blinded protocol, a team of three researchers allocated each documented thought to one of three possible categories: i) CMP (constituting the explicit monitoring or control of movements i.e., “Pick your feet up”); ii) Ruminations broadly related to the task (i.e., “Why can I not do this better?”), but also inclusive of threat-related attention (i.e., “Looking at what might trip me up”) and; 3) Other/miscellaneous (“What shall I have for lunch?”). However, only two participants reported a thought categorised as ‘Other/miscellaneous’. Therefore, only thoughts reported within CMP and rumination categories are documented. Unlike previous attempts to quantify the relative weighting of each thought category [19], our objective was to count the number of participants reporting thoughts within each category, and determine if older adults presenting higher MSRS scores do indeed self-report a greater number of CMP-related thoughts.

Participants were allocated in to two groups based on their MSRS score ('Low-Reinvestment' (*n*=11, mean MSRS score = 4.6/40, *SD* = 3.6), or 'High-Reinvestment' (*n*=10, mean MSRS score = 21.5/40, *SD* = 6.0), where the grouping threshold of 11/40 was determined using a median split. As the number of thoughts reported within each category were too low to permit a viable statistical analysis, descriptive statistics are documented.

2.2 Results

Analysis of retrospective thought processes revealed that there was no discernible between-group differences in the number of thought processes categorised as CMP or ruminations (Fig. 1).

*****Figure 1 here*****

2.3 Discussion

Results describing participants' self-reported thoughts indicate that, within the confines of a gait task, the MSRS is not sensitive at detecting conscious motor processes. These findings support those previously presented by Ellmers et al. [20], who described a lack of association between MSRS scores and self-reported conscious movement processing during gait in older adults. Instead, we propose that older adults may be misinterpreting items on the MSRS with reference to their engagement in ruminations or worrisome thoughts during gait (Fig. 1).

These results clearly advocate for the development of a new gait-specific scale capable of measuring CMP in addition to other associated factors (i.e., anxiety, ruminations and compromised processing efficiency [2]). The following section describes this process, in addition to a subsequent evaluation of the degree to which both the MSRS and newly-developed gait-specific scale predict specific aspects of gait performance in a separate cohort of older adults.

3. The Gait-Specific Attentional Profile validation and evaluation

3.1 Scale development

While the primary focus of the present study is the measurement of gait-specific CMP, questionnaire items were produced to measure several emotional and attentional processes relevant to the control of gait in older adults. These items were informed by the contents of the MSRS (e.g., “I am aware of the way my body moves” [16]), State-Trait Anxiety Inventory (e.g., “I feel calm” [21]), and Reinvestment Scale (e.g., “I get angry with myself for not walking/moving better” [22]).

To assess face validity, following production, these items were appraised by four expert researchers for suitability and were edited based on feedback. The scale was then administered to 6 older adults to assess font size, ambiguity, and wording [23], resulting in minor alterations. A total of 22 items were included in the scale for validation.

3.1.1 Exploratory Factor Analysis

Data were collected from 117 older adults (*M* age = 74.27, *SD* = 7.73) using the constructed scale. All participants included in the study were recruited from independent sheltered housing organisations, local community groups or through online advertisements publicised through community support networks. The sample size exceeded the minimum recommendation of five participants per item when conducting factor analysis [24]. All participants supplied informed consent. The questionnaire was distributed in either hard-copy (n=41 respondents) or online format (hosted by Bristol Online Surveys, Bristol, UK) (n=76 respondents). A 5-point Likert scale, anchored between 1 (“Not at all”) and 5 (“Very much so”) indicated a rating on all 22 items with two items (“I feel calm” and “I walk/move without thinking about it”) being coded in reverse. Participants were asked to indicate how they felt when they walked. While it was not feasible to determine pronounced cognitive deficits in online respondents, participants would have needed to operate a computer and access/navigate the online portal to complete the survey. All participants completing a hard copy questionnaire were able to hold a conversation with a researcher regarding their involvement. Any participant reporting a diagnosis of cognitive impairment was excluded from the study. Statistical comparison of the total G-SAP score (22 items) between the two modes of response revealed that scores were significantly higher in hard copy (*M* = 51.24, *SD* = 16.41) compared to online completions (*M* = 43.95, *SD* = 15.51), *U* = 1158.50, *Z* = -2.28, *p* = .022; a difference that we suggest is a consequence of the participant demographic encountered at sheltered accommodation venues compared to those actively engaging in research through online advertisements. Full details of the exploratory factor analysis can be found in Supplementary Material (Section 2).

3.1.2 Statistical analysis

Principle components analysis with varimax rotation and Kaiser normalisation was used to assign items to uncorrelated factors. Factors and items considered suitable for inclusion following extraction were defined by variables obtaining an eigenvalue greater than 1.00, and items within said factors loading at > 0.50 on one factor as well as items with cross-loading of factors > 0.20 between their two highest loading values.

3.1.3 Confirmatory factor analysis

A second sample of 107 older adults (*M* age = 78.79, *SD* = 9.96) completed the questionnaire for the purposes of the confirmatory factor analysis. The procedure for recruitment was reflective of that conducted for the exploratory factor analysis and resulted in 100 and 7 respondents for hard copy and online respondents, respectively (too few online respondents for statistical comparison between modes of response).

Full details concerning statistical analyses and model evaluation of the G-SAP are documented in Supplementary Materials (Sections 3-5) with analyses concerning internal consistency and repeatability (Sections 6 and 7, respectively). This process resulted in 11 items covering four emerging constructs: Anxiety ($G\text{-}SAP^{anx}$); Conscious Movement Processing ($G\text{-}SAP^{cmp}$); Fall-Related Ruminations ($G\text{-}SAP^{rums}$), and; Processing Efficiency ($G\text{-}SAP^{proc}$). The four emergent constructs and associated scale items are shown in Table 1.

*****Table 1*****

3.2 CMP association with gait characteristics

3.2.1 Participants

Fifty-three older adults (mean age = 74.7 ± 7.4 years, 16 males, 16/53 reported having fallen in the past 12 months) were recruited from local social groups. All participants gave written and informed consent and did not report having any diagnosed neurological or musculoskeletal conditions that significantly affected their walking. All participants also scored >18 on the Montreal Cognitive Assessment [25], indicating an absence of significant cognitive decline.

3.2.2 Protocol and analysis

Participants completed a single walk along a 6-meter automated GAITRite walkway (CIR Systems Inc., Havertown, PA) located in a quiet, well-lit laboratory. To allow for initial acceleration and terminal deceleration, start and stop points were marked on the floor 1.5 metres outside the start and end of the walkway capture area. Participants also completed the G-SAP (G-SAP^{cmp} M = 6.34, range = 3-5), MSRS (M = 23.09, range = 10-57) and an assessment of functional balance (BBS [18]; M = 52.58, range = 42-56).

The following gait variables were extracted from the GAITRite: Velocity (cm/s), step length (cm), base of support (cm) and double-limb support (% of gait cycle). These variables were selected due to their associations with experimentally-induced CMP [10,11]. Due to the single trial protocol used in the present research, it was not possible to calculate reliable measures of gait variability. Separate hierarchical two-stepped linear regression analyses (one regression per outcome variable) were performed on standardised outcome values. Given previously reported associations between MSRS and fall-status [26], an additional logistical regression was conducted on fall-status (whether participant had fallen in previous 12 months). Functional balance – the control variable – was entered in the first step, and predictor variables (G-SAP^{cmp} and MSRS scores) were entered in the second step.[1] The assumptions of homoscedasticity, error-independence (Durbin-Watson values all between 1.580-2.070), lack of multicollinearity (variance inflation factors<1.96, tolerances>0.51), and normal distribution of errors were verified for all analyses.

3.2.3 Results

The mean and range of the outcome (gait) variables are described in Table 2, along with the hierarchical regression analyses. Velocity values for one participant were excluded, due to a Z-score of 4.03.

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[1] Note, while the primary focus of the present research was to compare the added value of using G-SAP^{cmp} rather than the MSRS to predict CMP-related gait behaviours, additional regressions were also conducted to explore relationships between gait outcomes and the remaining G-SAP factors (G-SAP^{anx}, G-SAP^{rums} and G-SAP^{proc}). Please see Supplementary Materials (Table 4) for these analyses.

When controlling for functional balance, G-SAP^{cmp} significantly predicted: slower velocity (*p*=.033), shorter step length (*p*=.032) and greater double-limb support (*p*=.015), accounting for between 7-10% of variance. G-SAP^{cmp} did not, however, predict base of support (*p*=.815).

In contrast, MSRS scores did not significantly predict any gait outcome (all *p*s>.109). It is also noteworthy that the non-significant associations between MSRS and gait behaviour were in the *opposite* direction to G-SAP^{cmp} and previous reports of experimentally-induced CMP [8,10–12] (i.e., faster gait, longer steps, and reduced double-limb support).

When controlling for functional balance, neither G-SAP^{cmp} (*p*=.412) nor MSRS (*p*=.420) significantly predicted fall-status.

The G-SAP scale and data relating to the analyses above can be found at: https://osf.io/n7rcm/

*****Table 2*****

3.3 Discussion

3.3.1 CMP association with gait characteristics

The current study evaluated if scores from the MSRS and G-SAP^{cmp} predict a range of gait characteristics that are i) susceptible to change during manipulations of attentional focus [10], and ii) indicative of a 'conservative movement strategy' [5].

The results shown in Table 2 provide compelling evidence that G-SAP^{cmp} predicts a range of gait parameters, even when controlling for functional balance. However, no such relationship exists for the MSRS; a finding consistent with available evidence pertaining to spatiotemporal gait characteristics averaged across a given trial [15]. Previous research instead suggests the MSRS is associated primarily with behaviours indicative of processing inefficiencies and poor movement planning (e.g., longer stance duration prior to a precision step [13], increased number of visual fixations outside the intended walking path [27], or stopping walking when talking [9]). As indicated by our *Verbal reports protocol*, a possible explanation for this may relate to 'high-reinvestors' being more likely to engage in ruminative thoughts when walking (Figure 1). Such prevalent ruminations are likely to constitute verbal processes that will inevitably place demands on working memory. Evidence from dual-task protocols show that walking while concurrently performing a second verbal/cognitive task leads to changes in visual search and stepping behaviours [8,12,27] previously associated with high MSRS scores [9,13], including stopping walking when talking [9]. While ruminative thoughts might also account for compromised retention of external visuospatial information during gait [9], this rationale does not account for observations of 'high-reinvestors' demonstrating increased body awareness (providing a greater proportion of correct responses to questions about their movement) [9,26,28].

Collectively, these findings suggest that, while the MSRS provides a measure of general internal awareness, a context-specific tool (G-SAP^{cmp}) is required to measure CMP in the context of gait and predict CMP-related changes in gait performance. This is not surprising when considering that the MSRS was not designed as a clinical tool or task-specific measure, but rather a generic assessment of trait reinvestment.

3.3.2 CMP association with fall history

Neither the MSRS nor G-SAP^{cmp} significantly predicted participants' fall-history (Table 2). While in apparent contrast to previous reports identifying higher reinvestment in older adult 'fallers' [26], we suggest that the current null-results are a consequence of having included functional balance as a controlling variable. It is clear that walkers self-report CMP when perceiving their balance to be threatened [3,12]. However, the specific relationship to previous or future falls is not clear. In contexts where the habitual and automatic control of gait is largely preserved (i.e., where there is an absence of de-stabilising neurological or physiological decline), it is clear that CMP can serve to constrain motor performance (Table 2), leading to poor movement planning [3,12] and conservative ('overly cautious'[5]) gait (Table 2); changes that may, in turn, increase fall-risk, especially during dynamic and challenging tasks [2]. However, we argue that CMP should not be universally considered as a maladaptive consequence of concern about falling. In the context of ageing and neurorehabilitation, the adoption of CMP may represent a broadly beneficial response aimed at compensating for specific or general physiological or neurological deficits. In contrast, we suggest that constructs of rumination and processing inefficiencies can be more readily categorised as being detrimental.

3.3.3 G-SAP subscales of anxiety, task-irrelevant ruminations and processing efficiency

Results showed that G-SAP subscales of anxiety, ruminations and processing efficiency are not significantly associated with specific aspects of gait performance (see Supplementary

Materials, Table 4). While these observations are contrary to expectations, we maintain that both anxiety and ruminations will ultimately lead to inefficiencies in attentional processing [2,29]. Such inefficiencies would inevitably jeopardise cognitive or motor performance when task difficulty increases to a level where the performer can no longer compensate by increasing mental effort [6,8]. The level-ground gait task employed here may not have been sufficiently demanding to reveal potential cognitive inefficiencies associated with anxiety and/or ruminations. We also suggest that such inefficiencies are more likely to be evidenced by dual-task paradigms [30] or outcome measures indicative of compromised movement planning [2].

Results showed that G-SAP^{rums} and G-SAP^{proc} significantly predicted fall-status when controlling for functional balance (see Supplementary Materials, Table 4). While heightened ruminations and associated processing inefficiencies are a likely consequence of previous falls [20], their impact on gait behaviours (described above) warrants further investigation into the potential relationship with CMP, balance confidence, and future falls.

Compared to other constructs assessed by the G-SAP, processing efficiency is likely to represent a more challenging construct for walkers to self-appraise. While other G-SAP items attempt to directly assess the perceived construct, we suggest that the evaluation of processing efficiency must be achieved through an assessment of the perceived consequences of processing inefficiencies in generic terms, e.g., problems with multi-tasking and decision-making. As such, there is potential that processing inefficiencies could be realised in ways other than those targeted by G-SAP items (e.g., cognitive decline).

4. Conclusions

Our results show that the MSRS may not be sensitive to detect CMP (or related behaviours) during gait-specific tasks, thus providing a rationale for the lack of association between MSRS scores and altered gait performance (Table 2). We developed and validated a new self-reported measure (the ‘G-SAP’) of four psychological constructs implicated in influencing the control of balance and gait. Our results show that G-SAP^{cmp} is associated with gait velocity, step length and double limb support, even when controlling for functional balance; observations that corroborates findings from experimentally induced changes in CMP during gait tasks [8,10,12].

The G-SAP is intended for use by both researchers and clinicians. The G-SAP is envisioned to deliver two benefits: first, it may be used as a research tool to enhance our basic understanding of psychological factors influencing various aspects of movement planning and execution; a fundamental process to avoid misconceptions that have, hitherto, been evident in this topic. Second, the G-SAP could be utilised in applied (particularly clinical) contexts relevant to performance and rehabilitation of posture and gait. We suggest that future research should aim to evaluate these associations across a range of rehabilitation contexts to gauge the clinical utility, and to make recommendations for possible amendments.

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Table 1. *Factor names and associated items of the Gait-Specific Attentional Profile.*

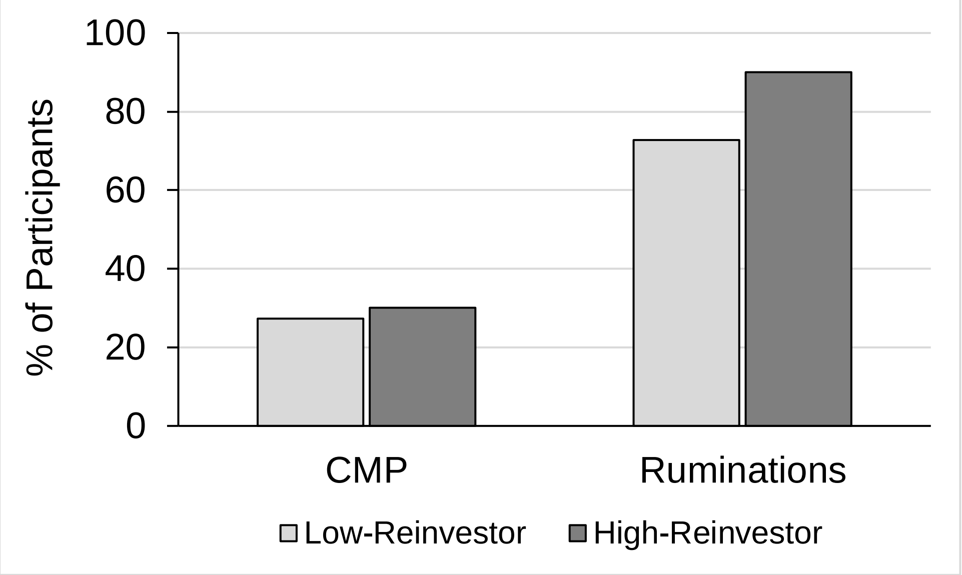
Factor Number	Factor Name	Item
Factor 1	Anxiety *(G-SAP^{anx})*	I feel strained I am concerned about what people think of my movements I feel tense
Factor 2	Conscious Movement Processing *(G-SAP^{cmp})*	I try to think about the way I walk/move I consciously try to control my movements I examine the way I walk/move
Factor 3	Fall-Related Ruminations *(G-SAP^{rums})*	I think about previous occasions when I lost my balance I think about what would happen if I fell Worrisome thoughts about falling run through my mind
Factor 4	Processing Efficiency *(G-SAP^{proc})*	I get confused and make illogical decisions I find it difficult to concentrate on two things at once

Table 2. *Hierarchical Regression Models with* ***G-SAP^{cmp}*** *and* ***MSRS*** *as predictors of gait performance, when controlling for functional balance.*

MODEL 1 Dependent variable: **Gait velocity** (*M* = 107.1 cm/s, range = 63.1-205.0 cm/s)			
	B (*SE*)	*p*	R^2
Step 1			.280 (***p*<.001**)
Functional balance (BBS)	.438 (.099)	**<.001**	
Step 2			.347 (***p*<.001**)
Functional balance (BBS)	.479 (.105)	**<.001**	
G-SAP^{cmp}	-.278 (.127)	**.033**	
MSRS	.217 (.135)	.114	
MODEL 2 Dependent variable: **Step length** (*M* = 60.3 cm, range = 35.7-83.8 cm)			
	B (*SE*)	*p*	R^2
Step 1			.224 (***p*<.001**)
Functional balance (BBS)	.474 (.123)	**<.001**	
Step 2			.296 (***p*=.001**)
Functional balance (BBS)	.526 (.130)	**<.001**	
G-SAP^{cmp}	-.348 (.157)	**.032**	
MSRS	.274 (.168)	.109	
MODEL 3 Dependent variable: **Base of support** (*M* = 10.6 cm, range = 3.2-23.9 cm)			
	B (*SE*)	*P*	R^2
Step 1			.134 (***p*=.007**)
Functional balance (BBS)	-.366 (.130)	**.007**	
Step 2			.135 (*p*=.066)
Functional balance (BBS)	-.372 (.144)	**.013**	
G-SAP^{cmp}	.041 (.174)	.815	
MSRS	-.033 (.186)	.862	
MODEL 4 Dependent variable: **Double-limb support** (*M* = 26.2%, range = 18.4-35.5%)			
	B (*SE*)	*p*	R^2
Step 1			.192 (***p*=.001**)
Functional balance (BBS)	-.438 (.126)	**.001**	
Step 2			.289 (***p*=.001**)
Functional balance (BBS)	-.460 (.131)	**.001**	
G-SAP^{cmp}	.401 (.158)	**.015**	
MSRS	-.210 (.169)	.218	
MODEL 5 Dependent variable: **Fall status** (*No. of fallers* = 16/53)			
	OR (*SE*)	*p*	R^2
Step 1			.001 (*p*=.829)
Functional balance (BBS)	.938 (.298)	.829	
Step 2			.023 (*p*=.661)
Functional balance (BBS)	.858 (.331)	.645	
G-SAP^{cmp}	1.386 (.398)	.412	
MSRS	.698 (.446)	.420	

Abbreviations: BBS = Berg Balance Scale; G-SAP^{cmp} = Conscious movement processing subscale of the Gait-Specific Attentional Profile; MSRS = Movement Specific Reinvestment Scale; OR = odds ratio, values >1 indicate increase in odds of being labelled a ‘faller’.

Figure 1. The percentage of Low- and High-reinvestor participants reporting at least one thought in categories of CMP and Rumination.



Supplementary Material

1. Factor analysis of Gait-Specific Attentional Profile

Maximum likelihood confirmatory factor analysis was conducted on suitable factor structures using SPSS AMOS software (IBM, Armonk, New York, USA) to account for any violations of multivariate and univariate normality. Chi-square statistics values, comparative fit index (CFI), standardize root mean square residual (SRMR), and root mean square error of approximation (RMSEA) were evaluated to assess the goodness of fit for each proposed factor structure. To determine the best fit when comparing different factor structures the Akaike information criterion (AIC) was calculated, with the lowest value constituting the best fitting model. A non-significant Chi-square test and a value < 3.00 when dividing the Chi-square value by the degrees of freedom have been suggested to be indicative of acceptable fit (for a review, see [1]). Values > 0.95 for CFI and < 0.08 for SRMR have been suggested to constitute good fit [2]. RMSEA values of < 0.05 and < 0.08 are suggested to represent good and acceptable fit respectively [3]. Following confirmation of good fit, the internal consistency and reliability of each contained factor of the selected model was assessed using Cronbach's alpha.

2. Exploratory Factor Analysis

Prior to the completion of the exploratory analysis, a correlation matrix of the items, the Kaiser-Meyer-Oklin (KMO) value, and Barlett's test of sphericity were examined to assess the suitability of the data. The KMO value was observed to be 0.91, (Cut off = 0.60, [4]), Bartlett's test of sphericity was statistically significant (χ^2 = 1546.83 (231), $p < 0.001$) and the correlation matrix yielded numerous values above 0.30, confirming the suitability of the data for factor analysis.

Four potential factor structures were suggested as a result of the exploratory factor analysis. A one-factor (43.88% of the variance), two-factor (52.18%), three-factor (58.39%), and four-factor models (63.57%; see Supplementary Table 1) were produced. With reference to the aims of designing the questionnaire and the theories underpinning the rationale, the 16 item four-factor model offered interesting distinctions with six items aligning with a factor seemingly reminiscent of assessing anxiety-related processes, four items related to the conscious processing of movement, three items to task-irrelevant ruminations about falling, and three items to inefficiencies of processing information. The 15-item three-factor model produced a factor featuring 8 items drawing parallels with those presented in the Movement Specific Reinvestment Scale, a second factor consisting of 4 task-irrelevant and anxiety-based questions, and a final factor comprising 3 items related to processing inefficiencies. Similarly, the 13 item two-factor model showed similar structure as the first two factors of the three-factor model, however the second 5-item factor also contained questions related to task-irrelevant ruminations, anxiety, and risk taking. The 19-item one-factor model was not considered suitable in assessing and isolating different emotional and attentional processes and was not submitted for confirmatory factor analysis.

3. Confirmatory Factor Analysis

The two-, three-, and four-factor models produced from the exploratory factor analysis were carried forward to the confirmatory factor analysis to test the suitability of each. Separate maximum likelihood analyses were conducted on each factor model.

4. Initial model fit indices

Whilst the two-factor model produced the lowest AIC value, the four-factor model was the only model to show a good level of fit using more than one of the indices (Chi-square divided by degrees of freedom statistic and RMSEA, see Supplementary Table 2). Additionally, there is a strong theoretical rationale for evaluating the validation of a scale which presented separate factors assessing anxiety, conscious movement processing, task-irrelevant ruminative thoughts, and processing inefficiencies.

5. Improvement of model fit

To improve the fit of the selected four-factor model, factor loading values and covariance modification indices were inspected (Supplementary Table 3). Three items were deleted on the basis of having low factor loadings (< 0.70 [5]). This resulted in improved values for the CFI (0.89), and AIC (270.81) when compared to the original four-factor model structure. An inspection of modification indices values for the remaining items was then performed to improve the remaining fit assessment parameters. Consistent with previous studies employing item removal during confirmatory factor analysis (e.g., [6]), a modification indices value larger than 10 indicated high covariance between items. Therefore, pairs of items with modification indices values greater than 10 were inspected and the item with the largest number of other covariance pairs was deleted. As presented in Supplementary Table 3, the removal of two items with high covariances, and the covarying of two other items, resulted in an improvement in the goodness of fit indices when compared to the original model. All values, aside from the Chi-square test, $\chi^2 = 69.75$ (37), $p < 0.05$, matched or surpassed the individual thresholds for good or acceptable fit (χ^2/df = 1.89, CFI = 0.97, SRMR = 0.04, RMSEA = 0.09, AIC = 127.75), presenting a suitable model for the validation of the questionnaire.

6. Internal consistency

Cronbach's alpha coefficient was calculated for the final four-factor model structure (see manuscript Table 1) using the data sampled for both the exploratory and confirmatory factor analyses (*N* = 224). Factors 1 to 4 produced values of 0.84, 0.89, 0.92, and 0.77 respectively. All factors provided internal consistency values in excess of the suggested minimum criterion value of 0.70 [7].

7. Test-retest reliability

To further test the suitability of the G-SAP, each factor produced from the four-factor model was tested for its test-retest reliability. The questionnaire was completed by 25 older adults (mean age = 73.8 ± 7.57) at two time points (Time 1 and Time 2) two weeks apart from one another. The resultant scores for each factor were calculated at each time point to allow for statistical difference testing between these two times. The G-SAP^{cmp}, G-SAP^{rums} and G-SAP^{proc} factor scores from Time 1 and Time 2 were subject to Paired Samples t-tests. As the G-SAP^{anx} scores at Time 1 and Time 2 where found to violate the assumption of normality, a Wilcoxon Signed Rank Test was completed. No statistically significant differences were observed for any of the comparisons (G-SAP^{anx}, $Z = 0.17$, $p = .87$; G-SAP^{cmp}, t (24) = 1.00, $p = .33$; G-SAP^{rums} t (24) = 1.03, $p = .31$; G-SAP^{proc}, t (24) = 1.30, $p = .21$), indicating that the factor scores could be successfully repeated by the same individuals without differences.

The test-retest reliability of each G-SAP construct was also assessed using Bland-Altman analyses and intraclass correlation coefficients (ICCs). Bland-Altman analyses (see Supplementary Fig. 1 and Supplementary Table 5) provided an indication of the variability between the measurement points. The mean of the difference between Time 1 and Time 2 ($\bar{d}$), as well as the standard deviation of the difference (SD_{diff}) were used in forming limits of agreement. Limits of agreement were calculated as $\bar{d} \pm (1.96 \times SD_{diff})$ [8]. All $\bar{d}$ values were close to 0 and the majority of values were between the limits of agreement, with 2 data points (G-SAP^{anx}, G-SAP^{cmp}, and G-SAP^{rums}) and 1 data point (G-SAP^{proc}) being beyond these limits in the respective plots. These findings indicate the constructs have some level of stability over time. Furthermore, the 95% confidence intervals (CI) of $\bar{d}$ were calculated to assess systematic bias. All 95% CI of $\bar{d}$ included zero, indicating no significant systematic bias was evident [8].

The ICCs and corresponding 95% CI were calculated using a single measurement, absolute-agreement, two-way mixed-effects model, as deemed appropriate for test-retest reliability [9]. The ICCs of each construct showed moderate (G-SAP^{proc}, ICC = 0.52, 95% CI = .17 to .75), good (G-SAP^{anx}, ICC = 0.62, 95% CI = .30 to .81; G-SAP^{cmp}, ICC = 0.89, 95% CI = .76 to .95), and excellent reliability (G-SAP^{rums} ICC = 0.91, 95% CI = .80 to .96) in accordance with published suggestions [9,10]. In combination, these multiple measures of test-retest reliability indicate that the G-SAP is a reliable method of assessing its relevant constructs.

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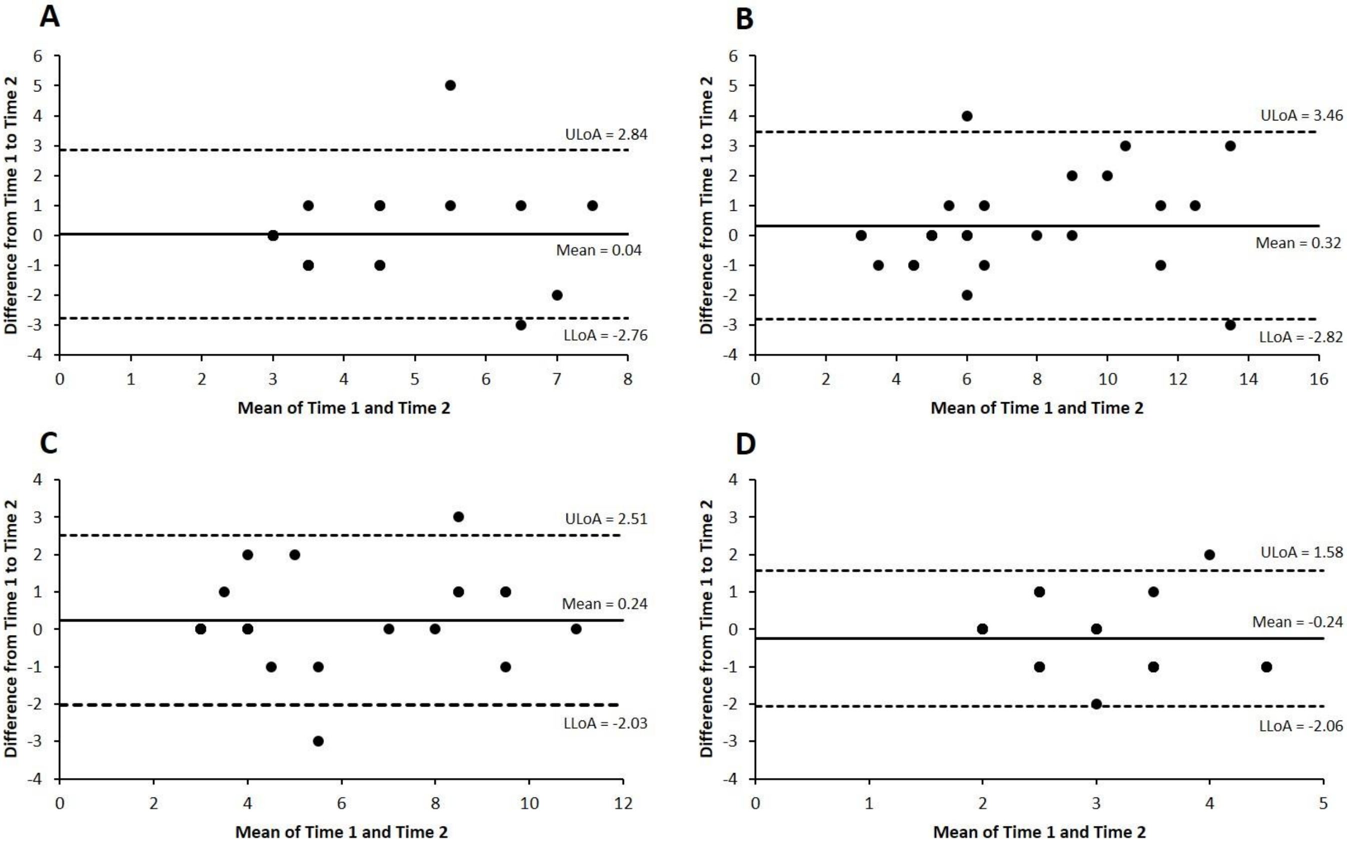

Supplementary Figure 1. *Bland-Altman plots for the test-retest reliability of (**a**) G-SAP^{anx}, (**b**) G-SAP^{cmp}, (**c**) G-SAP^{rums}, and (**d**) G-SAP^{proc}. Reference lines indicate the mean difference between Time 1 and Time 2 (solid line) and 95% limits of agreement (dashed lines). ULoA = Upper Limit of Agreement; LLoA = Lower Limit of Agreement.*

Supplementary Table 1. *Items and loadings for the four-factor model of the Gait-Specific Attentional Profile following varimax rotation with Kaiser normalisation during principle components analysis.*

Item	Factor Loadings			
	Factor 1	Factor 2	Factor 3	Factor 4
1. I feel strained	0.59*	0.38	0.36	0.26
2. I feel calm	0.61*		0.33	
3. I am concerned about what people think of my movements	0.66*	0.27		
4. I cannot think about what is happening around me				0.66*
5. I am aware of the way my body moves		0.64*		0.21
6. I think about previous occasions when I lost my balance			0.80*	
7. I think about what would happen if I fell	0.23		0.87*	
8. I get confused and make illogical decisions				0.75*
9. I walk/move without thinking about it		**0.57**	**0.40**	
10. Worrisome thoughts about falling run through my mind	0.31	0.22	0.63*	
11. I try to think about the way I walk/move	0.34	0.73*		
12. I try to figure out why I cannot walk/move better	0.70*	0.23		0.31
13. I try to perform tasks that I am no longer able to do safely			**0.42**	**0.44**
14. I consciously try to control my movements	0.27	0.75*	0.22	
15. I examine the way I walk/move	0.47	0.75*		
16. I feel tense	0.72*		0.32	

17. I tell myself how I should walk/move (e.g., pick feet up)	**0.44**	**0.63**		**0.23**
18. I feel self-conscious about the way I walk/move	0.71*	0.38		
19. I reflect about my movement	**0.52**	**0.66**		
20. I feel anxious that I might lose my balance	**0.48**	**0.20**	**0.63**	**0.24**
21. I find it difficult to concentrate on two things at once	0.30			0.65*
22. I get angry with myself for not walking/moving better	**0.59**			**0.43**

Note: * denotes the factor to which the item was assigned. Items in bold were removed.

Supplementary Table 2. *Initial model fit indices for the proposed different factor structures of the Gait-Specific Attentional Profile.*

Model	χ^2 (df)	χ^2/df	CFI	SRMR	RMSEA	AIC
Two-factor	205.51 (64)*	3.21	0.88	0.08	0.14	259.51
Three-factor	290.00 (87)*	3.33	0.86	0.07	0.15	356.00
Four-factor	279.99 (98)*	2.86	0.87	0.06	0.13	355.99

Note. * $p < 0.001$

Supplementary Table 3. *Model fit indices for the four-factor model of the Gait-Specific Attentional Profile following step-by-step removal or covariance of items.*

Order of Deleted/Covaried Items	Deleted or Covaried	Factor Number	Reason for Deletion/Covariation	Resultant Model Fit Indices Following Item Deletion/Covariation					
				χ^2 (df)	χ^2/df	CFI	SRMR	RMSEA	AIC
2. I feel calm	Deleted	1	Low factor loading (0.48)	270.45 (84)**	3.22	0.87	0.06	0.15	342.45
4. I cannot think about what is happening around me	Deleted	4	Low factor loading (0.56)	236.68 (71)**	3.33	0.88	0.07	0.15	304.68
5. I am aware of the way my body moves	Deleted	2	Low factor loading (0.67)	206.81 (59)**	3.51	0.89	0.07	0.15	270.81
18. I feel self-conscious about the way I walk/move	Deleted	1	High covariance with item 21 (MI = 19.87)	165.71 (48)**	3.45	0.90	0.06	0.15	225.71
6. I think about previous occasions when I lost my balance	Covaried with item 7	3	High covariance with item 7 (MI = 31.00)	121.63 (47)**	2.59	0.93	0.05	0.12	183.63
12. I try to figure out why I cannot walk/move better	Deleted	1	High covariance with item 15 (MI = 11.89)	69.75 (37)*	1.89	0.97	0.04	0.09	127.75

Note. Item numbers reported correspond to those in Table 1. MI; Modification Indices value. * $p < 0.05$, ** $p < 0.001$

Supplementary Table 4. *Hierarchical Regression Models with G-SAP^{anx}, G-SAP^{rums} and G-SAP^{proc} as predictors of gait performance, when controlling for functional balance.*

MODEL 1			
Dependent variable: **Gait velocity** (*M* = 107.1 cm/s, range = 63.1-205.0 cm/s)			
	B (*SE*)	*p*	R^2
Step 1			.280 (***p*<.001**)
Functional balance (BBS)	.438 (.099)	**<.001**	
Step 2			.362 (***p*=.001**)
Functional balance (BBS)	.354 (.114)	**.003**	
G-SAP^{anx}	-.195 (.156)	.217	
G-SAP^{rums}	-.239 (.156)	.132	
G-SAP^{proc}	.309 (.153)	**.049**	
MODEL 2			
Dependent variable: **Step length** (*M* = 60.3 cm, range = 35.7-83.8 cm)			
	B (*SE*)	*p*	R^2
Step 1			.224 (***p*<.001**)
Functional balance (BBS)	.474 (.123)	**<.001**	
Step 2			.295 (***p*=.002**)
Functional balance (BBS)	.391 (.143)	**.009**	
G-SAP^{anx}	-.362 (.195)	.070	
G-SAP^{rums}	-.078 (.189)	.684	
G-SAP^{proc}	.338 (.192)	.085	
MODEL 3			
Dependent variable: **Base of support** (*M* = 10.6 cm, range = 3.2-23.9 cm)			
	B (*SE*)	*P*	R^2
Step 1			.134 (***p*=.007**)
Functional balance (BBS)	-.366 (.130)	**.007**	
Step 2			.172 (*p*=.055)
Functional balance (BBS)	-.422 (.155)	**.009**	
G-SAP^{anx}	-.313 (.211)	.145	
G-SAP^{rums}	.080 (.205)	.699	
G-SAP^{proc}	.159 (.208)	.447	
MODEL 4			
Dependent variable: **Double-limb support** (*M* = 26.2%, range = 18.4-35.5%)			
	B (*SE*)	*p*	R^2
Step 1			.192 (***p*=.001**)
Functional balance (BBS)	-.438 (.126)	**.001**	
Step 2			.285 (***p*=.002**)
Functional balance (BBS)	-.295 (.144)	**.046**	
G-SAP^{anx}	.314 (.196)	.117	
G-SAP^{rums}	.251 (.190)	.194	
G-SAP^{proc}	-.331 (.193)	.093	
MODEL 5			
Dependent variable: **Fall status** (*No. of fallers* = 16/53)			
	OR (*SE*)	*p*	R^2
Step 1			.001 (*p*=.829)
Functional balance (BBS)	.938 (.298)	.829	
Step 2			.255 (***p*=.032**)
Functional balance (BBS)	.823 (.445)	.661	
G-SAP^{anx}	.840 (.593)	.768	
G-SAP^{rums}	4.007 (.599)	**.020**	
G-SAP^{proc}	.146 (.805)	**.017**	

Abbreviations: BBS = Berg Balance Scale; GSAP^{anx} = Anxiety subscale of the Gait-Specific Attentional Profile; GSAP^{rums} = Fall-related ruminations subscale of the Gait-Specific Attentional Profile; GSAP^{proc} = Processing inefficiency subscale of the Gait-Specific Attentional Profil; OR = odds ratio, values >1 indicate increase in odds of being labelled a ‘faller’.

Supplementary Table 5. *Bland-Altman analyses values for each G-SAP construct.*

Construct	Bland-Altman analyses					
	$\bar{d}$	SD_{diff}	SE of $\bar{d}$	95% CI of $\bar{d}$	LLoA	ULoA
G-SAP^{anx}	0.04	1.43	0.29	-0.55 to 0.63	-2.76	2.84
G-SAP^{cmp}	0.32	1.60	0.32	-0.34 to 0.98	-2.82	3.46
G-SAP^{rums}	0.24	1.16	0.23	-0.24 to 0.72	-2.03	2.51
G-SAP^{proc}	-0.24	0.93	0.19	-0.62 to 0.14	-2.06	1.58

Note. $\bar{d}$ = mean difference between Time 1 and Time 2; SD_{diff} = standard deviation of the mean difference; *SE* = standard error; 95% CI = 95% confidence intervals; LLoA = Lower Limit of Agreement; ULoA = Upper Limit of Agreement.