

ARTICLE

Development of the Flexibility in Daily Life scale to measure multidimensional cognitive and behavioural flexibility in health and disease

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Abstract

Objectives: Inflexibility of thought and behaviour is a transdiagnostic feature of many neuropsychiatric disorders and presents several empirical measurement challenges. Here, we developed and validated the Flexibility in Daily Life scale (FIDL); a novel, self-report questionnaire, which captures expressions of cognitive and behavioural flexibility in daily life and is sensitive to natural shifts in these processes across the adult lifespan.

Methods: The FIDL was developed using a deductive scale development approach, which aimed to capture common themes within the flexibility literature and across diagnoses (e.g. insistence on sameness, preference for routines). Following multidisciplinary consensus, an initial 37-item questionnaire was submitted for validation in an online sample of 295 healthy adult participants (19–78 years).

Results: Exploratory factor analysis produced a revised 21-item version comprising five factors, labelled: *Repetition, Switching, Predictability/Control, Routine, and Thoughts/Beliefs*. Internal consistency reliability was good-to-strong for the total FIDL score and moderate-to-strong for individual subscales. Convergent validity was established between the FIDL and an existing measure of cognitive flexibility. Critically, the FIDL total score evinced a U-shaped relationship with age, whereby flexibility was lower at the younger and older tails of the lifespan and greater in middle age. The same U-shaped trajectory emerged for the *Repetition, Routine, and Thoughts/Beliefs* factors.

Conclusions: Overall, the FIDL is a valid and reliable multidimensional measure of flexibility, which upholds a clearly defined factor structure and good psychometric

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properties. It promises to be a valuable clinical and research tool to assess the natural fluctuations in flexibility across the lifespan and departures thereof.

KEYWORDS

behavioural flexibility, cognitive flexibility, compulsivity, executive function, rigidity

Practitioner points

- We developed the Flexibility in Daily Life scale (FIDL) to capture natural expressions of cognitive and behavioural flexibility in daily life. The scale measures the capacity to switch between task sets or adopt alternative viewpoints and to flexibly engage in a diverse range of activities and behaviours in daily life.
- The FIDL was validated in healthy adults (19–78 years) and has a clearly defined factor structure, with robust psychometric properties. Five factors emerged, capturing repetitive and stereotypical behaviours (Repetition), the ability to adapt one's task or mental set (Switching), the preference for structured and ordered environments or social settings (Predictability/Control), the preference for routine (Routine), and rigid thinking styles or beliefs (Thoughts/Beliefs).
- Importantly, we demonstrated that the FIDL is sensitive to natural shifts in flexibility across the healthy adult lifespan. Specifically, the FIDL demonstrated a U-shaped relationship with age, whereby younger and older adults reported lower levels of flexibility, while peak flexibility was reported in middle age (~45–50 years).
- The FIDL provides a new validated tool to assess individual differences in multidimensional expressions of flexibility in daily life. We propose that the FIDL provides a much-needed clinical research tool that can be used transdiagnostically to detect subtle shifts in flexibility in health and disease.

INTRODUCTION

The capacity to adjust our thinking and behaviour in response to changes in the environment is an adaptive feature of human cognition that bestows immense flexibility in our daily lives (Armbruster et al., 2012; Dajani & Uddin, 2015; Ionescu, 2012; Scott, 1962). This propensity for cognitive and behavioural flexibility varies considerably between individuals and is suggested to undergo dynamic shifts across the lifespan (Anderson, 2002; Cepeda et al., 2001; Uddin, 2021) manifesting in a diversity of thoughts and behaviours. For example, prior work has documented a U-shaped relationship between age and one facet of flexibility (task switching), with greater switching capacity evident in middle age relative to younger and older participants (Cepeda et al., 2001; Kupis et al., 2021). Contemporary theories increasingly view cognitive and behavioural flexibility as trait level constructs that can be situated along a continuum (Morris & Mansell, 2018), the extremes of which represent maladaptive instances of entrenched rigidity on the one hand to unconstrained hyper-flexible thoughts and behaviours on the other (Armbruster et al., 2012; Uddin, 2021). Cognitive and behavioural inflexibility is a transdiagnostic feature of many neuropsychiatric disorders (Uddin, 2021), such as autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD; Dajani et al., 2016), traumatic brain injury (Pang et al., 2016; Whiting et al., 2017) and

neurodegenerative disease (Bozeat et al., 2000; Horne et al., 2023; Robbins & Cools, 2014; Townley et al., 2020). Therefore, efforts to improve the psychometric assessment of these constructs at a trait level represent a nascent topic in the field.

To date, formal assessment of cognitive flexibility has largely centred on the use of standard neuropsychological paradigms that probe the aspects of task switching (Braem & Egner, 2018; Rubinstein et al., 2001), set shifting (Hedden & Gabrieli, 2010; Wager et al., 2004), or reversal learning (Kehagia et al., 2010). The defining feature of such tasks is the requirement to switch between two mental sets, either in response to feedback or in response to explicit instruction. While informative in a clinical context, by focusing on isolated aspects of flexibility, these tasks fail to capture the full gamut of flexible thoughts and behaviours that are displayed across different contexts. This limits the ecological validity of existing tasks as performance on such measures does not necessarily correspond to flexible and inflexible expressions of thinking and behaviour as expressed in daily life (Dang et al., 2020; Geurts et al., 2009). Given that cognitive flexibility tasks also rely heavily on other executive functions such as inhibition and working memory (Buchsbaum et al., 2005; Dajani & Uddin, 2015; Hartman et al., 2001; Sánchez-Cubillo et al., 2009), the specificity of such tasks is further contentious. This is particularly true for task- and set-switching paradigms which require the maintenance of two or more rules in working memory and successful inhibition of the inappropriate response set (Dajani & Uddin, 2015). As most previous investigations into age-related changes in flexibility have relied on these paradigms (Anderson, 2002; Cepeda et al., 2001; Kupis et al., 2021), our understanding of cognitive and behavioural flexibility across the lifespan remains limited.

A growing body of evidence suggests that flexibility is multidimensional in nature (Barbey et al., 2013; Steinmetz et al., 2011; Strang et al., 2017) and potentially varies along several underlying factors, such as the preference for routine, restricted interests and insistence on sameness (Schultz & Searleman, 2002; Strang et al., 2017; Uljarević et al., 2023). As a result, several self- and informant-report questionnaires have been developed to capture discrete dimensions of flexibility in daily life. For instance, repetitive and inflexible behaviours in children and adolescents with autism spectrum disorder (ASD) are commonly assessed via carer-report using the Flexibility Scale (Strang et al., 2017) and the Dimensional Assessment of Repetitive Behaviour scale (DARB; Uljarević et al., 2023), while the Repetitive Behaviours Scale – Revised (Bodfish et al., 2000) measures repetitive behaviours in ASD from early childhood to middle age. However, each of these measures was designed specifically for use in ASD, rendering them unsuitable for broader transdiagnostic use.

Other measures, such as the Cognitive Flexibility Inventory (CFI; Dennis & Vander Wal, 2010) and the Cognitive Control and Flexibility Questionnaire (Gabrys et al., 2018), assess the ability to challenge and adapt maladaptive thoughts in adulthood, specifically in the context of stress. In contrast, the “Shift” scales on the Behaviour Rating Inventory of Executive Functioning (BRIEF, Gioia et al., 2015) and BRIEF Adult version (BRIEF-A; Roth & Gioia, 2005) have been validated across a broad range of neuropsychiatric conditions such as neurodevelopmental disorders, acquired brain injury, and neurodegeneration. However, these questionnaires are short unidimensional scales which are insufficient to parse the inherent heterogeneity of flexibility across the adult lifespan. As such, there is a crucial need for validated tools that can be applied transdiagnostically to capture individual differences in multidimensional flexibility and to identify alterations from normative function in heterogeneous mental disorders.

To this end, we developed a novel self-report questionnaire, entitled the Flexibility in Daily Life scale (FIDL). An extensive list of items was reviewed from existing tools within the neuropsychiatric literature. In consultation with a team of experts in neuropsychiatry, psychology, and neurology, 37 items were generated, which aimed to capture common themes across existing scales, in addition to frequent clinical observations. The current validation study investigates the psychometric properties of the FIDL in a large sample of healthy adults from 19 to 78 years old, including factor structure, reliability, and convergent validity, resulting in a final 21-item scale. In addition, the relationship between the FIDL and age is explored to determine whether the scale is sensitive to natural variations in flexibility across the adult lifespan.

METHODS

Participants

A total of 354 participants were recruited through Amazon Mechanical Turk using CloudResearch (formerly TurkPrime; Hauser et al., 2022; Litman et al., 2017; Litman & Robinson, 2020). Recruitment was stratified between four age groups (18–25, 26–40, 41–59, and 60+) with ~90 participants per group to capture the entire adult lifespan. Data quality was optimized using CloudResearch's Approved Participants (Hauser et al., 2022). The final sample included 295 participants following exclusions (Sex: 164 F, 129 M, 2 undisclosed; Mean age = 42.75, $SD = 17.34$, Range = 19–78).

Exclusion criteria included scoring <22 on an online version of the Mini-ACE (Hsieh et al., 2013), a general screen for cognitive impairment or sub-optimal attention, or where responses indicated automated completion by a bot (e.g., electronic signatures inserted into clock drawing space; $n = 47$). An additional 12 participants were excluded due to self-reported history of an acquired brain injury or a neurological condition. All participants were residents of the United States of America.

Participants were monetarily reimbursed for their time (\$3.00 USD). The study was approved by the local Ethics Committee (Approval number: 2021/873). All participants provided informed consent in accordance with the Declaration of Helsinki.

Procedures

Item development

An initial pool of 216 items was obtained following a review of existing questionnaires measuring cognitive and/or behavioural flexibility in neuropsychiatric populations (e.g., obsessive compulsive disorder, depression, neurodevelopmental disorders, and neurodegenerative disease). Questionnaires were included in this review if the overall questionnaire or one or more sub-scales specifically targeted cognitive or behavioural flexibility, or conversely, rigid, restricted, and/or repetitive patterns of behaviour. By leveraging tools from neuropsychiatry, we could ensure that we captured maladaptive expressions of inflexibility, which are characteristic features of neuropsychiatric disorders (Uddin, 2021). The inclusion of neuropsychiatric populations was also necessarily given the current lack of measures assessing daily manifestations of cognitive and behavioural flexibility in healthy populations. Importantly, the Cognitive Flexibility Index (CFI; Dennis & Vander Wal, 2010) was not included in this initial search as this measure was selected for subsequent convergent validity analyses and its inclusion would result in inflated validity estimates. We also elected not to include the Cognitive Control and Flexibility Questionnaire (Gabrys et al., 2018) as it measures the ability to control intrusive thoughts and emotions and to flexibly cope with stressful life events rather than providing a trait level assessment of flexibility. Where scales captured multiple constructs such as social cognition and sensory preferences, only the items measuring flexibility were extracted. A full list of the reviewed questionnaires is provided in [Table 1](#).

Multidisciplinary consensus

First, the initial 216 items were reviewed by the research team, following which 30 items capturing common themes within the flexibility literature were identified (e.g., insistence on sameness, preference for routine, intense interests, rigid ideas and opinions). Questions were re-written in a combination of positive and negative syntax and phrased in simple terms with appropriate examples to ensure suitability for a wide range of clinical populations and cultures.

The shortlist of 30 items was then presented for discussion at an international consortium on behavioural changes in neuropsychiatric and neurodegenerative populations. Consortium members include

TABLE 1 Questionnaires reviewed in FIDL item development.

Scale	Number of items extracted	References
BRIEF-A: “Shift” sub-scale	6	Roth and Gioia (2005)
CBI-R: “Stereotypic and Motor Behaviours” Scale	5	Wear et al. (2008)
Repetitive Behaviours Scale-Revised	22	Bodfish et al. (2000)
Cognitive Flexibility Scale	6	Martin and Rubin (1995)
Flexibility Scale	27	Strang et al. (2017)
Autism Quotient	21	Baron-Cohen et al. (2001)
AdAS Spectrum: “Inflexibility and adherence to routine” scale	63	Dell’Osso et al. (2017)
DARB	67	Uljarević et al. (2023)

Note: Questionnaires reviewed in the item development process are listed alongside the number of items extracted for the current study. Abbreviations: AdAS, Adult Autism Subthreshold Spectrum; BRIEF-A, Behaviour Rating Inventory of Executive Function, Adult version; CBI-R, Cambridge Behavioural Inventory Revised; DARB, Dimensional Assessment of Repetitive Behaviour.

neurologists, psychiatrists, and psychologists, from 14 countries. Following multidisciplinary discussion, a further 7 items were included to map onto common clinical observations of cognitive and behavioural inflexibility in neuropsychiatric and neurodegenerative populations. This resulted in a final set of 37 unique items, which was taken forward for validation (see [Supporting Information](#) for full item list).

Validation procedure

The study was conducted online via Qualtrics software (Provo, Utah, USA) and took approximately 20 minutes to complete. After providing informed consent, participants completed the FIDL and the Cognitive Flexibility Inventory (CFI; Dennis & Vander Wal, 2010) in a randomized order. All questions were self-paced. Participants then completed the online Mini-ACE (Hsieh et al., 2013) for screening purposes (see above exclusion criteria). All data were collected between June and August 2023.

When completing the FIDL, participants were asked to consider each statement in relation to the previous two weeks and to indicate the frequency with which each item had occurred on a 5-point Likert scale (“Never”, “Rarely”, “Sometimes”, “Often”, “All the time”). Each item was scored from 1 to 5, with higher scores indicating less flexibility. Positively worded items were reverse scored.

To establish the convergent validity of the FIDL, participants also completed the CFI as one of the most widely used and representative measures of cognitive flexibility in healthy adults. The CFI consists of 20 items designed to capture individual differences in cognitive flexibility in the context of stressful life events (e.g., “I consider multiple options before making a decision.”). Although the FIDL is designed to capture flexibility in a broader range of settings, the CFI was considered appropriate for use as a convergent validity measure because it measures a highly similar construct, which we would theoretically expect to be related to the FIDL. The CFI also comprises two subscales, measuring the ability to perceive multiple alternative explanations for life occurrences and to generate multiple alternative solutions to difficult situations (“Alternatives”), as well as the tendency to perceive difficult situations as somewhat controllable (“Control”). Participants responded to each item on a 7-point Likert scale (“Strongly disagree” to “Strongly agree”). Items were scored from 1 to 7, with higher scores indicating a more flexible style of thinking.

Statistical analysis

Data analyses were performed in R programming software (R Core Team, 2013) using the *psych* (Revelle & Revelle, 2015) and *Hmisc* (Harrell & Dupont, 2020) software packages. As full datasets are required

for factor analysis, multiple imputation was used to generate a complete dataset, employing the *mice* R package (Van Buuren & Groothuis-Oudshoorn, 2011). The original dataset had just .1% missing data.

Bartlett's test of Sphericity (Bartlett, 1950) and the Kaiser–Meyer–Olkin test (KMO, Kaiser, 1974) were used to evaluate the factorability of the data. Horn's parallel analysis of principal factors (Horn, 1965) was used to determine the optimal number of factors for extraction. This approach is widely recognized as the gold standard in factor analysis research (Frazier & Youngstrom, 2007; Hoelzle & Meyer, 2012; Velicer et al., 2000; Velicer & Fava, 1998; Watkins, 2018) and is preferable to alternative approaches such as Kaiser's criterion, which is more closely related to the number of variables analysed, rather than the underlying structure of the data (Fabrigar & Wegener, 2011; Hoelzle & Meyer, 2012; Izquierdo et al., 2014; Norris & Lecavalier, 2010).

An iterated principal axis exploratory factor analysis (EFA) was run using the promax (oblique) rotation method with an a priori factor loading cut-off of $\geq .40$ and a cross-loading cut-off of $\geq .30$ (Howard, 2016). An oblique rotation method was selected as we expected the factors to be correlated (Fabrigar & Wegener, 2011; Howard, 2016; Watkins, 2018). This step was repeated iteratively with the remaining items to determine the final factor structure.

The internal consistency of the resulting questionnaire was evaluated by calculating average inter-item and item-scale correlations, and Cronbach's alpha, for each factor and the overall FIDL score. In addition, split-half reliability was assessed by calculating Pearson's correlation between odd and evenly numbered items. To assess the convergent validity of the FIDL, correlations were computed between each FIDL factor and total FIDL score, with the CFI Total, Alternatives and Control scales. Pearson correlations or Spearman's Rho were used, depending on the multivariate normality. *p*-values were adjusted for multiple comparisons using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995), with a critical alpha level of .05.

Quadratic regression was used to determine the relationship between the FIDL total score and each subscale score with age, as visual inspection indicated that the data followed a U-shaped curve. The quadratic regression model was compared to the linear regression model to ensure that the quadratic term added significant variance to the model.

RESULTS

Exploratory factor analysis

Bartlett's test of Sphericity ($\chi^2[666] = 4526.88, p < .001$) indicated that the correlation matrix was not random, and the KMO statistic (.89) exceeded the recommended minimum ($\geq .70$; Hoelzle & Meyer, 2012; Lloret et al., 2017). Therefore, the 37-item questionnaire was considered appropriate for factor analysis and was submitted for EFA.

The initial EFA yielded a six-factor solution, as indicated by Horn's parallel analysis, which accounted for 45% of the total variance. Items with factor loadings $< .4$, and/or cross-loadings $\geq .30$ were removed, and the EFA was repeated with the remaining items. This process was repeated twice to derive the final five-factor structure which accounted for 49% of the total variance. The final solution consisted of 21 items with all loadings $\geq .4$ (see [Supporting Information](#) for revised questionnaire). Eigenvalues and the proportion of variance accounted for by each factor are presented in [Table 2](#).

Each factor was assigned a label based on the overarching theme across its respective items. Factor 1 was labelled "*Repetition*", reflecting repetitive and/or stereotypical behaviours and interests (e.g., "I need to repeat some actions/tasks until they feel 'just right'"). Factor 2, named "*Switching*", captured the ability to shift or adapt one's behaviour or mental set in response to feedback or changes in their environment (e.g., "I can easily change my approach if shown a better way"). Factor 3 was labelled "*Predictability/Control*", with items reflecting a need for structure and order in situations and/or others' behaviour (e.g., "I am very unsettled by last-minute changes to my plans."). Factor 4, labelled "*Routine*", described a preference for specific routines (e.g., "I like to follow specific routines when I leave the house..."). Finally,

TABLE 2 Exploratory factor analysis solution.

Factor number	Label	Eigenvalue	Proportion variance	Cumulative variance	Number of items
1	Repetition	5.78	.14	.14	6
2	Switching	1.97	.11	.25	5
3	Predictability/Control	1.02	.10	.36	4
4	Routine	.92	.07	.43	3
5	Thoughts/Beliefs	.67	.07	.49	3

Note: Five-factor solution and labels from principal axis exploratory factor analysis with promax (oblique) rotation.

Factor 5, named “Thoughts/Beliefs”, captured rigid or black-and-white thinking styles and beliefs (e.g., “I find it hard to let go of my ideas or beliefs, even when presented with new information.”).

Internal consistency reliability

The total FIDL score showed good internal consistency (Cronbach's alpha, $\alpha = .88$) and moderate-to-good internal consistency for each of the subscales (*Repetition*: $\alpha = .84$; *Switching*: $\alpha = .80$; *Predictability/Control*: $\alpha = .78$; *Routine*: $\alpha = .70$; *Thoughts/Beliefs*: $\alpha = .69$). Split-half reliability of the overall measure was strong ($r = .86$, $p < .001$). Mean inter-item correlations were moderate for all five subscales (*Repetition*: Mean $r = .46$; *Switching*: Mean $r = .44$; *Predictability*: Mean $r = .46$; *Routine*: Mean $r = .44$; *Thoughts/Beliefs*: Mean $r = .43$) falling within recommended guidelines (.15 to .50; Clark & Watson, 2019). The average inter-item correlation for the overall measure was .26, with moderate item-scale correlations across the subscales (*Repetition*: $r = .61$; *Switching*: $r = .58$; *Predictability/Control*: $r = .59$; *Routine*: $r = .52$; *Thoughts/Beliefs*: $r = .51$). The average item-scale correlation for the overall measure was also moderate ($r = .47$). Overall, these metrics demonstrate good internal consistency reliability for each individual factor and the total FIDL scale.

Convergent validity

Correlations between the total and individual factor scores of the FIDL and the CFI are presented in Table 3. The FIDL displayed good overall convergent validity with the CFI, as reflected by significant negative correlations between the Total FIDL and CFI Total, Control and Alternatives scales (all p values $< .05$), such that greater scores on the FIDL (denoting less flexibility), were associated with lower scores on the CFI (reflecting lower cognitive flexibility). Similarly, all FIDL Factor scores were significantly negatively correlated with the CFI total score and the CFI Control scale. However, only the *Switching* and *Thoughts/Beliefs* factors were significantly negatively correlated with the CFI Alternatives scale. This suggests that the FIDL *Repetition*, *Predictability/Control* and *Routine* scales capture unique aspects of flexibility to the CFI Alternatives scale, possibly due to their emphasis on behavioural rather than cognitive features. In summary, the FIDL displays good convergent validity with discrete aspects of the CFI (i.e. the Total CFI and Control subscale). Importantly, not all factors on the FIDL were associated with the CFI factors, suggesting the FIDL captures a broader range of flexible thoughts and behaviours. This is unsurprising given that the CFI is intended to measure specific aspects of flexibility within specific contexts and displays a two-factor structure, compared to the comprehensive five-factor structure of the FIDL.

Association between FIDL total score and age

Finally, we were interested to explore how expressions of flexibility might naturally shift over the course of the adult lifespan. A significant quadratic relationship was found between age and total FIDL

($t = 3.47$, $p < .001$), such that flexibility followed a U-shaped trajectory across the adult lifespan (see Figure 1). Specifically, self-reported flexibility was greatest in middle aged adults, with lower overall self-reported levels of flexibility at the younger and older tails of the lifespan. The model accounted for 11% of the variance, which was significantly greater than the linear regression model without the quadratic term ($F[1, 292] = 12.05$, $p < .001$).

Quadratic associations between FIDL dimensions and age

To determine whether distinct dimensions of flexibility underpin the above U-shaped relationship between age and Total FIDL, further regression analyses were run between age and each FIDL subscale. Quadratic relationships were found exclusively for the *Repetition* ($t = 3.186$, $p = .002$, $r^2 = .137$), *Routine* ($t = 2.837$, $p = .005$, $r^2 = .049$) and *Thoughts/Beliefs* ($t = 3.249$, $p = .001$, $r^2 = .041$) factors (see Figure 2)

TABLE 3 Correlations between FIDL and CFI scales.

Factor	CFI total	CFI alternatives	CFI control
1. Repetition	-.28**	-.04	-.39**
2. Switching	-.40**	-.30**	-.32**
3. Predictability	-.28**	-.02	-.40** ^a
4. Routine	-.18**	-.05 ^a	-.21** ^a
5. Cognitive	-.28**	-.20**	.23**
FIDL total	-.41**	-.15*	-.47**

Note: * $p < .05$; ** $p < .01$; All correlations are Spearman's Rho unless otherwise specified (^aPearson's r). p values are corrected for False Discovery Rate at $q = .05$ using the Benjamini–Hochberg procedure.

Abbreviations: CFI, Cognitive Flexibility Inventory; FIDL, Flexibility in Daily Life scale.

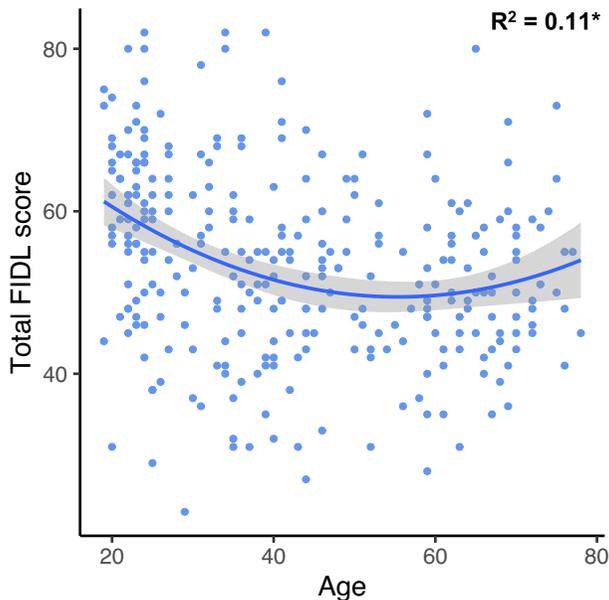


FIGURE 1 Relationship between total flexibility scores on the FIDL and age. Figure depicts quadratic regression between FIDL total flexibility scores and age, where higher FIDL scores denote lower self-reported levels of flexibility. Shaded area depicts 95% confidence interval; * $p < .001$; formula: $FIDL = .009(Age)^2 + -.981(Age) - 76.651$.

whereby self-reported flexibility was greatest in middle age and lower at the younger and older tails of the adult lifespan.

Interestingly, we observed subtle variations in the trajectory of these changes across individual FIDL subscales. Specifically, the *Thoughts/Beliefs* and *Routine* factors were lowest (denoting greater flexibility) at approximately 45 years of age. This suggests that individuals are most open to alternate ideas and viewpoints and least insistent on routines during middle age. In contrast, lower scores on the *Repetition* subscale occurred slightly later (~50 years), reflecting the age at which individuals are least likely to seek out repetitive and stereotypical behaviours. These factors underwent a progressive shift towards lower flexibility from approximately 50 years of age for the *Thoughts/Beliefs* and *Routine* factors, and at approximately 60 years for the *Repetition* scale.

Linear associations between FIDL dimensions and age

In contrast, the quadratic term was non-significant for the *Switching* ($t = 1.446, p > .05$) and *Predictability/Control* ($t = 1.337, p > .05$) factors (see Figure 3), which were better characterized by a linear relationship.

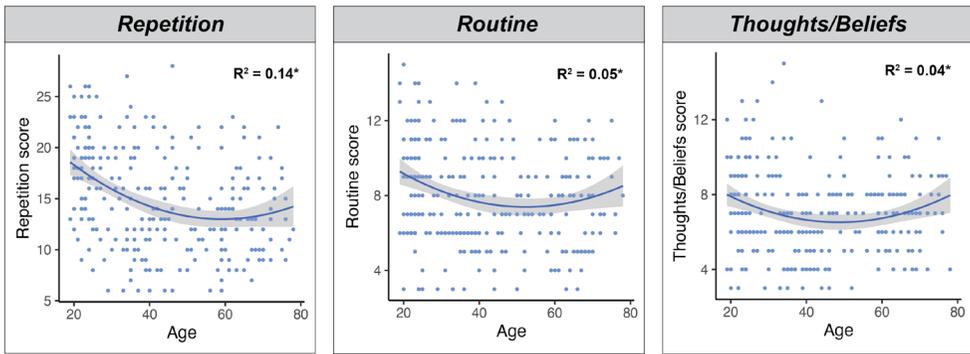


FIGURE 2 Quadratic associations between age and distinct dimensions of flexibility on the FIDL. Figure depicts quadratic regressions between FIDL Repetition, Routine and Thoughts/Beliefs subscale scores and age; Shaded areas depict 95% confidence intervals; $*p < .001$; Regression formulas: Repetition = $.004(\text{Age})^2 + -.410(\text{Age}) + 25.104$; Routine = $.002(\text{Age})^2 + -.178(\text{Age}) + 12.057$; Thoughts/Beliefs = $.002(\text{Age})^2 + -.163(\text{Age}) + 10.492$.

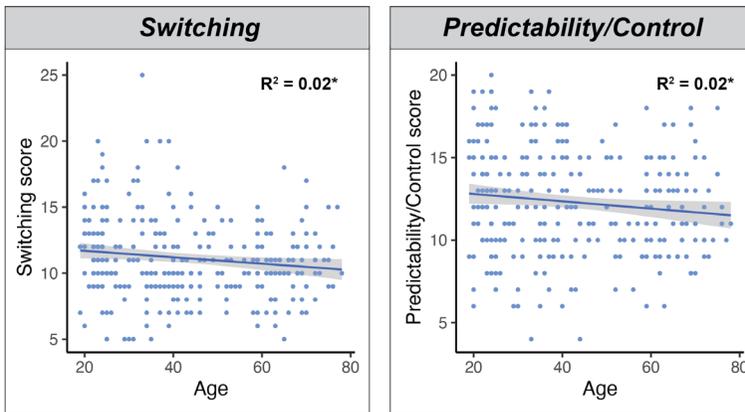


FIGURE 3 FIDL subscales demonstrating linear associations with age. Figure depicts linear regressions between FIDL Switching and Predictability/Control subscale scores and age. Shaded areas depict 95% confidence intervals; $*p < .001$; Regression formula: Switching = $-.024(\text{Age}) + 12.183$; Predictability/Control = $-.022(\text{Age}) + 13.241$.

Specifically, both factors displayed a significant negative association with age (*Switching*: $\beta = -.02, p = .017, r^2 = .019$; *Predictability/Control*: $\beta = -.02, p = .035, r^2 = .015$), such that self-reported flexibility increased across the lifespan. This finding suggests that as individuals get older, they report slight improvements in their ability to adapt their task or mental set, along with a reduced need for predictability and order in their daily life. However, it is important to note that both regressions were characterized by a gradual slope, suggesting only subtle changes in these factors across the lifespan.

DISCUSSION

Flexibility of thought and behaviour is crucial for adaptive functioning and appears to be compromised across a wide array of neuropsychiatric and neurological disorders (Uddin, 2021). Progress in this field has been hampered by a lack of validated empirical tools that are sensitive to natural variations in multidimensional flexibility and can be used transdiagnostically. Here, we present the FIDL as a robust new measure that effectively captures individual differences in the diversity of flexible thoughts and behaviour that manifest in daily life. Our findings indicate that the FIDL is a valid and reliable measure, with a clearly defined factor structure, and is sensitive to naturally occurring changes in flexibility across the adult lifespan. Importantly, we demonstrate that subcomponents of flexibility, as indexed by the FIDL, follow distinct trajectories across different timepoints of the adult lifespan, providing critical windows from which deviations from normative function might be tracked.

Considering first the psychometric properties of the FIDL, an exploratory factor analysis produced a revised 21-item scale with a five-factor solution. The emergent factors captured the following constructs: repetitive and stereotypical behaviours (*Repetition*), the ability to adapt one's task or mental set in response to changes in the environment or feedback (*Switching*), the preference for structured and ordered environments or social settings (*Predictability/Control*), the preference for routine (*Routine*), and rigid thinking styles or beliefs (*Thoughts/Beliefs*). The 21-item FIDL exhibited good to strong internal consistency, whereas all sub-scales had moderate to strong internal consistency. Furthermore, associations between the FIDL total and individual subscales and an established measure of cognitive flexibility, the CFI (Dennis & Vander Wal, 2010), further provided evidence for the convergent validity of the new scale. Although the correlations observed were relatively modest, all associations ran in the predicted direction, suggesting that discrete dimensions of flexibility as indexed by the FIDL correspond to the Control and, to a lesser extent, Alternatives subscales of the CFI. This is unsurprising given that the FIDL incorporates core aspects of cognitive flexibility which form the cornerstone of the CFI, such as the ability to consider multiple viewpoints and think flexibly about situations. Importantly, however, the FIDL enriches the assessment of flexibility by incorporating additional behavioural features, such as repetitive and stereotyped behaviours, whilst sampling a broader range of cognitive aspects such as the presence of rigid and unchanging thoughts and beliefs, providing a more comprehensive assessment of multidimensional flexibility.

A notable finding of our study was that overall flexibility followed a U-shaped curve across the adult lifespan, with lower flexibility at either tail of the distribution. Self-reported flexibility was observed to increase from early to middle adulthood (~40 years), following which it progressively approached a more inflexible style of interacting with the world in older adulthood (~60 years). This trajectory is broadly consistent with previous work demonstrating a u-shaped relationship between age and switching task performance (Cepeda et al., 2001; Kupis et al., 2021; Schultz & Searleman, 2002; Uddin, 2021), providing further support for the construct validity of the FIDL. Considerable variability has been reported in the literature in terms of the relationship between flexibility and age. For example, some studies have found a linear decline in task switching abilities with age (Kray & Lindenberger, 2000; Wecker et al., 2005), or simply that older adults are less adept at overcoming existing cognitive biases when compared to younger adults (Wilson et al., 2018). In contrast, meta-analytic research has demonstrated no evidence for an effect of age on task-switching costs after accounting for general slowing (Chen & Hsieh, 2023). As such, it has been suggested that the manner by which flexibility is assessed

has considerable bearing on the results elicited (Chen & Hsieh, 2023). These mixed findings likely also reflect the multidimensional nature of flexibility, whereby discrete components of this construct may be differentially affected by the aging process. Our finding of distinct age-related trajectories on individual subscales of the FIDL suggests this, indeed, may be the case. A gradual reduction in flexibility in older age resonates well with the shifting mental mode framework, which proposes a bias towards exploitative rather than exploratory decision-making as the foundation for all forms of thought and behaviour in healthy aging (Spreng & Turner, 2021). Accordingly, the predisposition towards exploitation in older adults manifests in a bias towards less flexible forms of thinking and behaviour.

Notably, our findings suggest that this age-related transition towards a more exploitative mental mode does not occur uniformly across all dimensions of flexibility. Using the FIDL we could estimate the onset of distinct shifts in flexibility across the adult lifespan. Critically, of the three dimensions to display a U-shaped relationship with age, we observed distinct shifts at different temporal timescales for each of the *Repetition*, *Routine*, and *Thoughts/Beliefs* factors. The earliest shift in mental mode was found to occur at ~50 years (*Thoughts/Beliefs*, *Routine*), followed by a second shift at ~60 years in which repetitive behaviours became more prominent (*Repetition*). Collectively, these subscales provide important information regarding expected natural shifts towards exploitative modes of thinking and behaviour, from which departures from normative function can be tracked.

From a clinical perspective, the FIDL can be used to reconcile several conflicting findings in the literature. First, we demonstrate the need to deconstruct the overall construct of flexibility into distinct subcomponents, each of which likely follows separable trajectories across the adult lifespan. The inherent multidimensionality of flexibility likely can account for some of the previous challenges in conceptualization and assessment of this construct (Dajani & Uddin, 2015; Uddin, 2021), particularly the poor agreement between neuropsychological tasks and existing questionnaires (Dang et al., 2020; Geurts et al., 2009; Uddin, 2021). For instance, the FIDL *Switching* factor describes the ability to switch between mental sets in response to a change in the environment or feedback, and aligns well with the type of flexibility assessed in neuropsychological task- and set-shifting paradigms. However, our results indicate that this dimension is separable from other behavioural manifestations of inflexibility in daily life such as the insistence on routine, or the preference for predictability and familiarity. This multidimensional framework could also explain paradoxical findings of inflexibility alongside distractibility in clinical populations, as is often the case in comorbid ASD and attention-deficit/hyperactivity disorder (ADHD; Uddin, 2021).

One limitation of the current study is that we did not validate the measure in a second, independent sample. Future work using confirmatory factor analysis (CFA) in a new independent sample will be essential to corroborate the factor structure reported here. Additionally, as the current validation study was limited to a healthy adult population, a crucial next step will be to validate the FIDL in clinical populations in which inflexibility is reported. Such populations include, but are not limited to, ASD and ADHD (Dajani et al., 2016), traumatic brain injury (Pang et al., 2016; Whiting et al., 2017), neurodegenerative disease (e.g. frontotemporal dementia [FTD], Parkinson's disease, Alzheimer's disease; Bozeat et al., 2000; Horne et al., 2023; Robbins & Cools, 2014; Townley et al., 2020), and obsessive-compulsive disorder (OCD; Akkermans et al., 2019; Gruner & Pittenger, 2017). Such validation studies will determine whether the dimensional architecture of flexibility differs across disease aetiologies, and will facilitate the establishing of clinical cut-off points to determine maladaptive expressions of inflexibility. Finally, although the current version of the FIDL is designed exclusively for use in adulthood, we note the potential to modify the measure for use in childhood or adolescence. This would enable us to adopt a whole-of-life approach to trajectories of flexibility and to chart its course longitudinally.

In summary, the FIDL is a novel and validated measure of multidimensional cognitive and behavioural flexibility suitable for use across the adult lifespan. The scale upholds good psychometric properties, is sensitive to natural fluctuations in flexibility across the adult lifespan, and suitable for use transdiagnostically. Integration of the FIDL into neuropsychological test batteries at large will enable the creation of reliable thresholds from which departures from normative function can be determined. This represents a crucial next step to map the underlying cognitive and neural determinants of

disease-specific profiles of inflexibility, to understand their functional implications, and to ultimately arrive at a comprehensive taxonomy of flexibility in health and disease.

AUTHOR CONTRIBUTIONS

Kristina Horne: Conceptualization; data curation; formal analysis; writing – original draft; methodology. **Tao Chen:** Conceptualization; writing – review and editing; methodology. **Muireann Irish:** Conceptualization; writing – original draft; methodology; supervision; writing – review and editing; funding acquisition; resources.

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CONFLICT OF INTEREST STATEMENT

This authors report no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study will be made openly available in a public repository prior to publication.

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SUPPORTING INFORMATION

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