Processing speed, working memory and reasoning ability from childhood to old age

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A B S T R A C T

The study investigated whether theoretical causative relations among declining cognitive abilities during adulthood and old age conform to a literal reversal of improving cognitive development during childhood. Children aged 8–14 years (n = 240) and adults aged 18–87 (n = 238) completed the same battery of psychometric tests, which defined latent traits for processing speed, working memory, and reasoning ability. Speeded performance improved during childhood and slowed across the adult range. Childhood performance was well described by a developmental cascade, whereby increasing chronological age is accompanied by faster processing speed, which influences improved working memory, which in turn influences improving reasoning ability. However, although adult performance resembled a cascade with diminishing reasoning ability mediated by processing speed and working memory, this was not a mirror image of the cascade for children. The main difference with adults was a direct causal path between age and working memory. Post hoc analysis located this among adults aged 55 years and over. This suggests that, whereas childhood cognitive development is substantially mediated by processing speed, declining reasoning ability in old age is influenced by slower processing speed but also by age-related change(s) influencing working memory that are independent from processing speed.

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1. Introduction

This study tested a suggestion by Jensen (2006) that putative changes in brain structure responsible for declining cognitive abilities during adulthood and old age may be a mirror image of structural changes responsible for improving cognitive development during childhood. This proposition derives from theory that identifies individual differences in processing speed as central to an understanding of intelligence differences and also attributes average changes in cognitive abilities during childhood and old age to speed changes. There are well established average changes in speed with age on perceptual speed and elementary cognitive tasks like reaction times (RT) and inspection time (IT), whereby processing becomes faster during childhood and adolescence but slows throughout adulthood. Thus, Kail (1991) established that improvement to processing speed is more rapid during younger years but tends to asymptote close to early adult levels by about 14 years of age. Similarly, Salthouse (1996) summarized evidence that processing speed declines on average across adult years from 20 to 80, the mean trend being approximately linear.

Salthouse (1996) has developed a theory that substantially attributes age-related, reduced effectiveness of higher order cognitive functioning to general slowing in processing speed, which imposes a fundamental constraint on the efficiency of working memory. Thus, because only brief retention is possible without rehearsal, slower processing results in slower execution of ongoing operations and poorer synchronization of task components. In turn, a more limited working memory adversely impacts cognitive decision making.

Salthouse’s theory resembles what Fry and Hale (1996) described as a “cognitive developmental cascade”, that is, a sequence of processing stages within which the effectiveness of processing at the first stage has a flow-on effect for the next stage, which influences the next, and so on. Fry and Hale described childhood cognitive maturation in terms of causal relations between increasing chronological age, processing speed, working memory, and fluid intelligence, by cross-sectional comparisons across years 7–19. Path analysis confirmed a developmental cascade whereby age-related faster processing speed resulted in improved working memory, which linked to higher fluid performance (as demonstrated in Fig. 1). After controlling statistically for age, Fry and Hale found that individual differences in speed influenced memory, and when both age and speed were controlled, working memory influenced fluid performance. Fry and Hale also discounted the possibility that age-related improvement in fluid ability was responsible for faster processing speed, by demonstrating marked, constant age differences across different speeded tasks in age samples matched on raw ability scores. The cascade model therefore provided a good account for average mental age changes and for ability differences within age bands, in processing speed, working...
memory and reasoning. Kail (2007) confirmed these results, also showing that the cascade explanation held longitudinally for reasoning on a re-test after one year.

One interpretation of these results is that maturing brain structures improve processing speed, with concurrent improvement in working memory and other cognitive functions. These structures achieve optimal capacities by early adulthood but then gradually deteriorate across the adult years. As Jensen (2006, p. 97) has surmised, “the overall picture of mental decline . . . as shown by chronometric tests is much like a mirror image of the developmental curves from early childhood to maturity”. However, although this account appears consistent with changes in the psychological constructs outlined here, it is possible that cognitive deterioration during old age involves more than simply the reverse of whatever maturational changes improve capacities during childhood. If changes in old age reflect other than a mirror image of childhood development, it should be possible to identify differences between trends during childhood and old age.

Gregory, Nettelbeck, Howard, and Wilson (2009) reported a more complex cascade for people aged 70–91 years. They found significant paths from age to fluid reasoning via perceptual speed and working memory. However, cross-sectional and longitudinal analyses also found direct paths between age and working memory and between perceptual speed and reasoning. Gregory et al. therefore concluded that relations between age, processing speed, working memory and reasoning ability are more complex among elderly adults than among children, perhaps because of age-related changes other than slower speed that might directly impact working memory. They also proposed that a direct path from processing speed to reasoning could reflect confounding by motor problems.

The present study extends previous research by testing the cascade model cross-sectionally for an age range from 8 to 80 years. The test battery was selected to define latent variables for process- ing speed, working memory and reasoning ability during adulthood and old age. That is, older age causes slower processing speed, which causes poorer working memory, which results in poorer reasoning ability. As with the childhood model, significant coefficients linking age to the latent variables are limited to causal paths from age to processing speed, from processing speed to working memory and from working memory to reasoning ability.

Support for both hypotheses would be consistent with Jensen’s (2006) suggestion that cognitive changes in old age are a mirror image of the developmental trends found from early childhood to adulthood.

![Fig. 1. Theoretical developmental cascade. PS = Perceptual speed, WM = working memory, RA = reasoning ability.](image-url)

### 2. Method

#### 2.1. Participants

Participants numbered 478 (288 males, 190 females; M = 28.1 years, SD = 21.7), recruited into four non-overlapping age groups. These samples of convenience provided a wide age range from childhood to old age. Youngest children were assumed capable of understanding all test requirements in the common battery. Children were in two groups, both readily accessible within metropolitan schools: 8–10 years (mid-primary education n = 120, M = 9.69 years, SD = 0.76) and 12–14 years (early secondary education n = 120, M = 13.3 years, SD = 0.74). Adults formed two non-overlapping groups, split around middle age so as to maximise age differences; 18–45 years (younger, n = 146, M = 30.8 years, SD = 7.7) and 55–87 years (older, n = 92, M = 67.3 years, SD = 8.2). They were recruited from the general community via advertisement. Adults were paid Australian $30.

#### 2.2. Materials

Participants completed the following common battery.

2.2.1. Processing speed (PS)

Four of the five tests were drawn from O’Connor and Burns (2003), who found that these loaded on a well-defined second order general speed factor.

2.2.2. Digit Symbol

Wechsler Adult Intelligence Scales-IV (WAIS-IV); 2-min time limit, number correct.

2.2.3. Visual Matching


2.2.4. Inspection time (IT, Nettelbeck (2001))

The target figure was two vertical lines joined at the top by a horizontal line. The shorter vertical line appeared to left or right with equiprobability. A warning cue (520 ms) preceded the target. The target Fig. appeared for varying SOA1, dependent on accuracy. Exposure was controlled by a backward pattern mask (370 ms). The participant indicated location of the shorter line by pressing the left or right key on the computer mouse. Instructions emphasized accuracy. Following practice, IT estimation began with SOA 250 ms and followed an adaptive staircase algorithm, which required three correct responses at any SOA before reducing SOA by 17 ms. Following an error, SOA increased by 17 ms. IT (ms) was the average SOA calculated over eight reversals of direction on the staircase (associated probability for correct response .79).

2.2.5. Simple reaction time (RT)

The apparatus was a scaled down version of the panel described by Jensen and Munro (1979). One light was illuminated, immediately above the home button. Participants depressed the home button and, following light onset, released the button as quickly as possible. Sixty trials followed 10 practice trials, with a pseudo-random period of 1–8 s between each. Median RT (ms) was measured as duration between light onset and button release.

2.2.6. Odd man out – decision time (DT, Frearson & Eysenck (1986))

Apparatus was as for simple RT. For each trial, three of eight possible lights were illuminated, with two adjacent and one fur-

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1. Stimulus-onset-asynchrony: time between target onset and mask onset.
ther away. Participants responded to the latter (“odd-man-out”). There were 20 practice trials, followed by 60 trials. Median OMO-DT (duration between lights onset and home button release) was recorded for correct responses.

2.2.7. Working memory (WM)

WM was defined by three tests used by Burns, Nettelbeck, and McPherson (2009), together with a widely used test of span memory.

2.2.8. Picture Swaps (Stankov (2000))

Items consisted of three different cartoon pictures (animals, familiar objects), presented simultaneously on the computer screen in different locations (position 1, 2 or 3). Participants made a series of mental “swaps” between locations as quickly and accurately as possible (e.g. “swap 2 and 3”). A response (6-choice alternatives) was registered on the computer keyboard’s number pad. The task had four levels: one swap (6 trials), two swaps (6 trials), three swaps (12 trials), and four swaps (12 trials). So as to index WM capacity, the measure was total correct responses in 20 min or, if fewer than two correct responses were made within any six consecutive trials, at termination time.

2.2.9. Picture Recognition (modelled on the test from WJ – R)

Participants tried to remember one to seven pictures presented on the computer screen for 5 s. These were followed by a new set of two to six numbered pictures, one to four of which were in the original presentation. On-screen instructions indicated how many were from the original stimulus set. Participants indicated pictures seen previously using the number pad. Following practice, there were 30 trials that became progressively more difficult. A trial was scored as correct only if all pictures were recognised. The task ended either when participants scored zero on six consecutive trials, or after 30 trials.

2.2.10. Digit Span (modelled on the test from WAIS-IV)

Single digits, 1–9, were presented one at a time on the computer screen for 1 s. Immediately following, participants attempted to reproduce the sequence, in the same order, entering digits consecutively via the number pad. The task began at a span level of one digit, with four trials at each span level. Maximum span level tested was 9. A minimum of two correct trials at any span level was required to proceed to the next level. Maximum correct score was 36.

2.2.11. Reasoning ability (RA)

Cattell Culture Fair Test (computerized version of Scale 2, Form A). This has four subtests: Series, Classification, Matrices, Conditions (time limits 3 min, 4 min, 3 min, 2.5 min, respectively, as per manual). Following practice there were 12, 14, 12, and 8 test items for Series, Classification, Matrices and Conditions, respectively. Participants could not return to an item having entered a response for that item. Number correct was recorded for each subtest.

2.3. Procedure

The protocol had approval from the University of Adelaide Human Research Ethics Committee. Children had written parental consent and adult participants affirmed informed consent in writing. Children were tested at schools in groups of up to six, over two sessions of 50 min each. Adults attended the laboratory individually, completing the test battery in a single session lasting two hours including rest breaks.

2.4. Statistical analyses

Latent variable analyses using all available data were conducted using maximum likelihood estimation (MPlus v5.1; Muthén & Muthén, 2007). Model fit was assessed by chi-square-test of exact fit, comparative fit index (CFI), Tucker Lewis index (TLI), root mean square error of approximation (RMSEA) and its 90% confidence intervals (CI90), and standardized root mean square residual (SRMR).

3. Results

Table 1 shows descriptive statistics for all variables, for the entire sample and the four age subsamples. Fig. 2 shows the means of standard scores for Digit Symbol, Visual Matching, reflected RT, reflected odd-man-out DT, together representing PS, regressed on age. There is an obvious reversal in direction of the relationship between PS and age beyond 20 years. We therefore initially tested the cascade model on two groups; children 18–14 and adults 18 years and older.

Table 2 shows correlations between all variables for these two groups, with children above the diagonal and adults below. Fig. 3 illustrates the developmental cascade model instantiated by our data. In addition to age, three latent variables represent PS (Digit Symbol, Visual Matching, IT, simple RT, and odd-man-out DT); WM (Picture Swaps, Picture Recognition, and Digit Span); and RA (Series, Classifications, Matrices, and Conditions from Cattell Culture Fair).

Table 1

<table>
<thead>
<tr>
<th>Subtest</th>
<th>M (N = 478)</th>
<th>SD</th>
<th>Range</th>
</tr>
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<tbody>
<tr>
<td>Digit Symbol</td>
<td>60.0</td>
<td>16.9</td>
<td>24–112</td>
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<tr>
<td>Visual Matching</td>
<td>41.6</td>
<td>11.5</td>
<td>16–65</td>
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<td>Inspection time (ms)</td>
<td>72.7</td>
<td>29.5</td>
<td>25–274</td>
</tr>
<tr>
<td>Simple RT (ms)</td>
<td>262</td>
<td>40.1</td>
<td>180–436</td>
</tr>
<tr>
<td>Odd-man-out DT (ms)</td>
<td>760</td>
<td>414</td>
<td>309–5590</td>
</tr>
<tr>
<td>Picture Swaps</td>
<td>22.7</td>
<td>9.24</td>
<td>0–36</td>
</tr>
<tr>
<td>Picture Recognition</td>
<td>17.5</td>
<td>4.34</td>
<td>5–29</td>
</tr>
<tr>
<td>Digit Span</td>
<td>20.3</td>
<td>5.97</td>
<td>1–35</td>
</tr>
<tr>
<td>Series</td>
<td>8.89</td>
<td>1.93</td>
<td>0–12</td>
</tr>
<tr>
<td>Classifications</td>
<td>7.84</td>
<td>1.99</td>
<td>0–13</td>
</tr>
<tr>
<td>Matrices</td>
<td>8.73</td>
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<td>0–12</td>
</tr>
<tr>
<td>Conditions</td>
<td>4.89</td>
<td>2.12</td>
<td>0–8</td>
</tr>
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</table>

Note: Ns varied across tests. For any test, minimum listwise N = 443 and n = 117 (8–10 years), n = 109 (12–14 years), n = 139 (18–45 yrs), n = 78 (55+ yrs). For the whole sample there were complete data for n = 425.
SRMR = .05; CFI = 1.0, SRMR = .01, respectively) and adults (CFI = .99, SRMR = .05; CFI = 1.0, SRMR = .00)\textsuperscript{2}.

As shown in Fig. 3, there are six possible causal paths on the structural model. Age predicts PS, WM, and RA (hereafter paths 1, 2, and 3, respectively); PS predicts WM and RA (paths 4 and 5); and WM predicts RA (path 6). This model was tested separately for children and adults. First, the full model was tested. Second, statistically non-significant paths were set to zero and the Wald test used to compare the more constrained and full models. A final model that retained only statistically significant paths was then fitted.

For children the full cascade model fit was: $\chi^2 (60) = 113.4$, $p < .001$, CFI = .95, TLI = .93, SRMR = .05, RMSEA = .06, CI\textsubscript{90} = [.043, .078]. Paths from age to WM and RA, and from PS to RA were not statistically significant. Setting these to zero and testing the effect of these constraints via the Wald test found no significant deterioration in fit $\chi^2 (3) = 3.27$, $p = .35$. The fit of the final model was $\chi^2 (63) = 123.7$, $p < .001$, CFI = .94, TLI = .93, SRMR = .05, RMSEA = .06, CI\textsubscript{90} = [.047, .080]. Standardized parameter estimates for this model are shown in Fig. 4a. This result was therefore consistent with previous findings, with children’s performance well described by a cascade, from age to PS, to WM, to RA.

For adults the full cascade model fit was: $\chi^2 (60) = 110.9$, $p < .001$, CFI = .96, TLI = .95, SRMR = .05, RMSEA = .06, CI\textsubscript{90} = [.042, .077]. Paths from age and PS to RA (3, 5) were not statistically sig-

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**Table 2**

<table>
<thead>
<tr>
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<th>1</th>
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<tr>
<td>3. Inspection time</td>
<td>-.490</td>
<td>-.483</td>
<td>.365</td>
<td>.339</td>
<td>-.367</td>
<td>-.322</td>
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<td>-.222</td>
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<td>-.283</td>
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<td>4. Simple RT</td>
<td>-.418</td>
<td>-.407</td>
<td>.273</td>
<td>.360</td>
<td>-.387</td>
<td>-.378</td>
<td>-.357</td>
<td>-.308</td>
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<td>-.324</td>
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<td>5. Odd-man-out DT</td>
<td>-.440</td>
<td>-.394</td>
<td>.396</td>
<td>.344</td>
<td>-.321</td>
<td>-.291</td>
<td>-.259</td>
<td>-.401</td>
<td>-.206</td>
<td>-.289</td>
<td>-.298</td>
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<td>7. Picture Recognition</td>
<td>.541</td>
<td>.520</td>
<td>-.493</td>
<td>-.299</td>
<td>-.323</td>
<td>.492</td>
<td>.316</td>
<td>.234</td>
<td>.282</td>
<td>.363</td>
<td>.419</td>
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<td>8. Digit Span</td>
<td>.442</td>
<td>.412</td>
<td>-.424</td>
<td>-.292</td>
<td>-.281</td>
<td>.554</td>
<td>.444</td>
<td>.251</td>
<td>.216</td>
<td>.344</td>
<td>.323</td>
<td></td>
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<td>9. Series</td>
<td>.505</td>
<td>.503</td>
<td>-.476</td>
<td>-.254</td>
<td>-.393</td>
<td>.585</td>
<td>.587</td>
<td>.521</td>
<td>.319</td>
<td>.364</td>
<td>.314</td>
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<td>10. Classifications</td>
<td>.390</td>
<td>.385</td>
<td>-.365</td>
<td>-.322</td>
<td>-.376</td>
<td>.399</td>
<td>.420</td>
<td>.378</td>
<td>.552</td>
<td>.461</td>
<td>.411</td>
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<tr>
<td>11. Matrices</td>
<td>.518</td>
<td>.503</td>
<td>-.443</td>
<td>-.273</td>
<td>-.378</td>
<td>.537</td>
<td>.561</td>
<td>.458</td>
<td>.643</td>
<td>.526</td>
<td>.404</td>
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<tr>
<td>12. Conditions</td>
<td>.469</td>
<td>.449</td>
<td>-.365</td>
<td>-.308</td>
<td>-.366</td>
<td>.578</td>
<td>.463</td>
<td>.428</td>
<td>.541</td>
<td>.435</td>
<td>.506</td>
<td></td>
</tr>
</tbody>
</table>

Note: All correlations calculated using pairwise deletion for missing values; ns range from 216 to 239 for children and from 208 to 236 for adults.

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SRMR = .05; CFI = 1.0, SRMR = .01, respectively) and adults (CFI = .99, SRMR = .05; CFI = 1.0, SRMR = .00)\textsuperscript{2}.

As shown in Fig. 3, there are six possible causal paths on the structural model. Age predicts PS, WM, and RA (hereafter paths 1, 2, and 3, respectively); PS predicts WM and RA (paths 4 and 5); and WM predicts RA (path 6). This model was tested separately for children and adults. First, the full model was tested. Second, statistically non-significant paths were set to zero and the Wald test used to compare the more constrained and full models. A final model that retained only statistically significant paths was then fitted.

\textsuperscript{2} With three indicators WM was a just identified model, so that the fit had to be perfect.
significant. Setting these to zero and testing the effect of these constraints via the Wald test showed no significant deterioration in fit $\chi^2 (2) = 1.02, p = .60$. The fit of the final model was $\chi^2 (62) = 112.2, p < .001$, CFI = .97, TLI = .96, SRMR = .05, RMSEA = .06, CI90 = [.041, .075]. Standardized parameter estimates are shown in Fig. 4b. This model was similar to that for the children but differed in one important respect; there was a direct path from age to working memory, as found by Gregory et al. (2009).

To gauge further the extent to which these models mirrored one another, we examined the relative loadings of the manifest variables on the three latent variables in the two models. Establishing full measurement invariance here is not relevant because the means of the latent variables were not expected to be the same; the sign of the regression for children of PS on age was reversed from that for adults; and the regression of WM on age was fixed at zero in children but freely estimated in adults. However, the extent to which the point estimates of the manifest variables within each group fall within the confidence intervals for these in the other group provides an indication of similarity. As seen from Table 3, although there was some overlap between the 95% confidence intervals across children and adults, in only 10 from a possible 24 comparisons did a point estimate for one group fall within the range for the other group.

Finally, we explored further whether the direct causal path between age and WM held throughout the full span of the adult age range. We fitted and refined the cascade model (as described above) to data for the younger adults (18–45 year olds, $n = 146$) and the older participants (55–87 years, $n = 92$). For 18–45 year-olds the fit statistics and model parameters were $\chi^2 (63) = 68.90, p = .29$, CFI = .99, TLI = .98, RMSEA = .03, CI90 = [.00, .06]. This model did not include a causal path between age and WM. For the older adults, after including the direct path between age and WM, fit statistics and model parameters were $\chi^2 (62) = 84.00, p = .03$, CFI = .93, TLI = .91, RMSEA = .08, CI90 = [.02, .09].

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Children</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Symbol → PS</td>
<td>.75 [.68, .82]</td>
<td>.89 [.85, .93]</td>
</tr>
<tr>
<td>Visual Matching → PS</td>
<td>.79 [.73, .85]</td>
<td>.87 [.83, .92]</td>
</tr>
<tr>
<td>Inspection Time → PS</td>
<td>.49 [.38, .60]</td>
<td>.62 [.53, .72]</td>
</tr>
<tr>
<td>Simple RT → PS</td>
<td>.66 [.57, .74]</td>
<td>.48 [.37, .58]</td>
</tr>
<tr>
<td>Odd-man-out DT → PS</td>
<td>.38 [.26, .50]</td>
<td>.28 [.16, .40]</td>
</tr>
<tr>
<td>Picture Swaps → WM</td>
<td>.70 [.61, .79]</td>
<td>.77 [.71, .84]</td>
</tr>
<tr>
<td>Picture Recognition → WM</td>
<td>.63 [.54, .73]</td>
<td>.72 [.65, .79]</td>
</tr>
<tr>
<td>Digit Span → WM</td>
<td>.56 [.46, .67]</td>
<td>.67 [.58, .75]</td>
</tr>
<tr>
<td>Series → RA</td>
<td>.53 [.43, .64]</td>
<td>.82 [.77, .88]</td>
</tr>
<tr>
<td>Classifications → RA</td>
<td>.60 [.50, .70]</td>
<td>.64 [.55, .72]</td>
</tr>
<tr>
<td>Matrices → RA</td>
<td>.69 [.60, .78]</td>
<td>.77 [.71, .83]</td>
</tr>
<tr>
<td>Conditions → RA</td>
<td>.65 [.55, .74]</td>
<td>.68 [.60, .76]</td>
</tr>
</tbody>
</table>

Fig. 3. Developmental cascade model showing all possible causal paths. PS = perceptual speed, WM = working memory, RA = reasoning ability, DS = Digit Span; VM = Visual Matching, IT = inspection time, RT = odd-man-out decision time, Sw = Picture Swaps, PR = Picture Recognition, Sp = Digit Span, Se = Series, Cl = Classification, Ma = Matrices, Co = Conditions.

Fig. 4. (a) Final structural model for children showing standardized parameter estimates. PS = perceptual speed, WM = working memory, RA = reasoning ability, DS = Digit Span; VM = Visual Matching, IT = inspection time, RT = odd-man-out decision time, Sw = Picture Swaps, PR = Picture Recognition, Sp = Digit Span, Se = Series, Cl = Classification, Ma = Matrices, Co = Conditions. (b) Final structural model for adults showing standardized parameter estimates. PS = perceptual speed, WM = working memory, RA = reasoning ability, DS = Digit Span; VM = Visual Matching, IT = inspection time, RT = simple reaction time, DT = odd-man-out decision time, Sw = Picture Swaps, PR = Picture Recognition, Sp = Digit Span, Se = Series, Cl = Classification, Ma = Matrices, Co = Conditions.
4. Discussion

Hypothesis 1 was supported, confirming a developmental cascade for children and adolescents, as found by Fry and Hale (1996). PS and WM mediated improved reasoning ability with age, with 70% of variance in PS accounted for by age, with PS accounting for 66% of variance in WM and the latter accounting for 78% of variance in RA.

With adults, however, the simple cascade consistent with Salt house (1996) was not found. Instead, results confirmed a direct path from age to WM as reported by Gregory et al. (2009) and under circumstances where the latent variable has been more clearly defined. Moreover, the relative loadings of manifest to latent variables within the models for children and adults were markedly different, with fewer than half of the possible comparisons between a manifest loading on the latent variable falling within confidence intervals for the other group and with the three latent variables appreciably less well differentiated among the children than among the adults.

Although Fig. 2 suggests slow linear decline in PS, with comparable scatter across the adult years, as expected from past research, performance among 18–45 year-olds was substantially superior to that of 55–87 year-olds on all tests except SRT (refer to Table 1). This provided a priori grounds to explore further whether the direct causal path in the adult cascade model between age and WM held throughout the full age range. Despite the smaller numbers involved, both the model for 18–45 year-olds and that for 55–87 years fitted the data well; but it was necessary to include the direct path between age and WM for the older group.

These results suggest that the simple developmental cascade model describing childhood cognitive development is reversed at around 20 years of age and that the reversed trend may prevail until middle age. Beyond about 55 years, however, the onset of old age appears to be accompanied by age-related changes independent from processing speed. Taken together, the differences between the models for children and particularly older adults were not consistent with Jensen’s (2006) suggestion that the childhood developmental cascade model and the model that describes cognitive change during old age are mirror images of one another. In short, therefore, whereas the simple cascade model provides a good description for the trajectory of improving performance during childhood, and declining performance during early adulthood, the model that applies to deteriorating performance during old age is more complex.

However, even among older adults we did not find a direct path from PS to RA, as reported by Gregory et al. (2009) and it is possible that their result reflected a speed constraint on Raven’s scores, although similar speed constraints also applied here to the four subtests in the Cattell Culture Fair Test. Arguably, these time constraints were sufficiently severe to cause confounding between power and speed aspects of this test and future research should explore this issue. Similarly, beyond fitting five speeded tasks to a latent processing speed model, this study has not addressed the question of whether speed of processing is well described as a single, task-independent construct. Thus, it is clear from Fig. 4 that there were considerable differences between the five speeded tests used here in the extent to which the different tasks tapped processing speed as defined here. IT and DT showed much higher specificity than the other three tests and future research should seek to determine what additional sources of variance other than speed these tasks are measuring.

To summarize, the implication of these results is that the cascade model for maturing childhood cognition and the model that describes cognitive decline during old age are not simply mirror images of one another. Slower processing is causatively linked to cognitive decline in old age, moderating the relationship between age and WM, and accounting for about 78% of WM variance. This is substantial but other unidentified age-related variables, independent from processing speed, also appear to exert a direct influence on WM. Our data offer no leads as to what these influences might be. However, one possibility, speculative but worth exploring, is that individual differences may exist in age-related deterioration in the short-term span component of WM. If so, this may be independent from processing speed, which may principally affect attentional aspects of WM (Burns et al., 2009).

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References


Footnote 1 We are grateful to an anonymous reviewer for this suggestion.