The Development and Diversity of Cognitive Flexibility: Greater Cultural Variation in Early
Rule Switching than Word Learning

Cristine H. Legare^a, Michael T. Dale^a, Sarah Y. Kim^a, & Gedeon O. Deák^b

^a Department of Psychology, The University of Texas at Austin

^b Department of Cognitive Science, University of California, San Diego

Abstract

Cognitive flexibility, the adaptation of representations and responses to new task demands, improves dramatically in early childhood. It is unclear, however, whether flexibility is a coherent, unitary cognitive trait that develops similarly across populations, or is an emergent dimension of task-specific performance that varies across populations with culturally variable experiences. Children from two populations that differ in pre-formal education experiences completed two distinct tests of cognitive flexibility, matched for complexity. Three- to 5-year-old English-speaking U.S. children and Tswana-speaking South African children completed two language-processing cognitive flexibility tests: the FIM-Animates, a word-learning test, and the 3DCCS, a rule-switching test. U.S. and South African children did not differ in word-learning flexibility, showing similar age-related increases. In contrast, only U.S. preschoolers showed an age-related increase in rule-switching flexibility; South African children did not. Working memory explained additional variance in both tests, but did not modulate the interaction between population-sample and task. The data suggest that rule-switching flexibility may be more dependent upon culturally-variable educational experience, whereas word-learning flexibility may be less dependent upon culturally-specific input.

Keywords: cognitive development, cognitive flexibility, cross-cultural comparison, executive functioning, rule switching, South Africa, word learning

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Children live in culturally-constructed niches full of knowledge systems, practices, artifacts, and institutions that vary substantially between populations. Acquiring the diverse knowledge and skills of their social groups requires a cognitive system that is highly responsive to different ontogenetic contexts and cultural ecologies (Legare & Harris, 2016; Nielsen, Haun, Kaertner, & Legare, 2017). Young children normatively acquire the beliefs and practices of the social group that they are born into, an extraordinary learning achievement that requires substantial species-level ontogenetic adaptability (Legare, 2017).

Our prolonged early development facilitates the acquisition of complex cultural practices and beliefs (Legare & Nielsen, 2015). Natural selection favored an extended juvenile period that allows for extensive interaction with caregivers and peers, thus facilitating social learning (Bjorklund & Causey, 2017; Hublin, 2005). The delayed maturation of cognitive control in young children may allow children to rapidly learn the foundational skills and knowledge that adult cognition is built upon (Bjorklund & Ellis, 2014; Gopnik et al., 2017; Lucas, Bridgers, Griffiths, & Gopnik, 2014; Romberg & Saffran, 2010; Thompson-Schill, Ramscar, & Chrysikou, 2009).

Flexible cognition refers to the adaptive modification of attention, representations, and action policies in response to new task demands and ecological constraints (Deák, 2004). Cognitive flexibility allows humans to build upon established behaviors by relinquishing old solutions and flexibly switching to more productive, efficient, or innovative ones (Davis, Vale, Schapiro, Lambeth, & Whiten, 2016). Flexible cognition is challenging (i.e., resource-demanding) when individuals have multiple conflicting representational or behavioral options, and when they must

select and integrate specific stimulus properties, task cues, and information from working and long-term memory (Luchins, 1942; Luchins & Luchins, 1950).

Cognitive flexibility improves dramatically from 3 to 6 years (Deák, 2000; Zelazo et al, 2003; Zelazo, Frye, & Rapus, 1996). During this age span, children (living in industrialized countries, and attending formal schools) improve in switching between verbal rules for sorting cards (Zelazo et al., 1995), in using changing semantic cues to infer novel word meanings (Deák, 2000), and in other tests of cognitive flexibility (e.g., Davidson, Amso, Anderson & Diamond, 2006; Deák, Ray, & Pick, 2004; Dibbets & Jolles, 2006). This age-related pattern suggests development of a *general* cognitive trait.

The nature of this trait, however, has been a matter of debate. Age-related changes in early childhood have been attributed to representational complexity (Zelazo & Frye, 1998), representational capacity (Perner, 1992; Perner & Lang, 2002), cognitive inhibition (Zelazo et al., 2003), attentional inhibition (Kirkham et al., 2003), working memory strength (Munakata, 1998), and task or cue comprehension (Chevalier & Blaye, 2009; Deák, 2004; Holt & Deák, 2015). Resolving the causes of age-related change has been difficult for at least two related reasons: first, multiple factors might contribute to the development of cognitive flexibility (e.g., Kehagia, Murray, & Robbins, 2010). Second, most research has used one standard task, and has studied only children of educated parents in relatively affluent and predominantly English-speaking communities. These factors make it unclear whether flexibility develops as a coherent, unitary cognitive trait (Deák & Wiseheart, 2015), or as a patchwork of content-specific but largely independent skills.

Recent evidence from middle class children in the United States (hereafter, U.S. children) suggests a partial dissociation between two kinds of flexibility: word-learning and rule-following.

That is, on tests matched for complexity and difficulty, high socioeconomic status U.S. 3- to 5-year-old children show a low correlation between word-learning and rule-switching flexibility (Deák & Wiseheart, 2015). This might imply that different experiences, which vary within and between populations, support different kinds of flexibility. For example, most young children in most cultures encounter unfamiliar words. Although the density and diversity of this experience varies across children (Hart & Risley, 1995), regular exposure to *some* novel and less-familiar words is likely a near-universal experience for very young children across cultures and communities. By contrast, young children's experience with reasoning about abstract, arbitrarily changing symbolic mappings may vary widely (see Deák, 2004). Some children might seldom encounter situations that demand such reasoning; others might experience those situations normatively in the form of games, text-centered interactions, and structured preschool activities, particularly those involving symbolic manipulatives. Although experiences like these might vary widely across children and cultures, most research on the development of flexibility has used a test that demands exactly this sort of reasoning. In the most common test of cognitive flexibility, a version of the intra/extradimensional reversal shift tests of the 1960s (e.g., Esposito, 1975; Mumbauer & Odom, 1967) called the *Dimensional Change Card Sorting* test, children follow instructions to switch from sorting two drawings by shape to sorting by color, or vice versa (Zelazo et al., 1996). Children's interpretation and response to this task might depend on their experience engaging in activities that impose arbitrary rules or instructions for manipulating abstract representations (Deák, 2004; Deák & Wiseheart, 2015).

We hypothesize that children's rule-switching skill depends at least in part upon their specific educational experiences. Children exposed regularly and early to preschool activities that involve abstract symbolic mappings, as well as arbitrary instructions to make rule-based responses,

might perform better on rule-switching tasks than children with less exposure to such activities. High-quality preschool curricula normatively incorporate organized and structured rule-governed activities, so children with more preschool experience, or the equivalent, might have an advantage in rule-switching tests (Lan et al., 2009). That is, it is possible that even in young children, school experience contributes to cognitive flexibility.

Indirect evidence suggests that such a contribution is possible. Notably, a strong relationship has been observed between the development of cognitive flexibility, and formal educational experience. For example, *executive functions* predict academic achievement. The cognitive processes often considered to be primary executive functions include inhibition and interference control, working memory, and cognitive flexibility, all of which contribute to controlled cognitive skills such as goal-directed planning (Barkley, 2012; Diamond, 2013; Jurado & Rosselli, 2007). Preschool and kindergarten children's behavioral self-regulation and executive functioning is correlated with higher achievement in mathematical assessments (Blair & Razza, 2007). A behavioral self-regulation task (Head-Toes-Knees-Shoulders) that measures cognitive flexibility, working memory, and inhibitory control (McClelland et al., 2007; Ponitz et al., 2008) predicts academic achievement in U.S. kindergarten children (Ponitz et al., 2009; McClelland et al., 2014). The HTKS task was also administered in a large study across four countries (U.S., South Korea, Taiwan, and China), and the results showed that behavioral regulation (HTKS) correlated with better mathematics performance in children from all four countries, and with better early literacy in all countries where literacy was measured (Wanless, McClelland, Acock, Ponitz, Son, Lan, et al., 2011).

Cross-cultural research on executive functioning has also shown the impact of culturally variable experience in development. Notably, several studies have compared the performance of

young East Asian and Western children, who typically have early experience with formal schooling and/or preschool activities (e.g., Norenzayan et al., 2002). Chinese and Korean preschool children outperform U.S. children on measures of executive functioning (e.g., inhibition and rule switching measures) (Oh & Lewis, 2008; Sabbagh et al., 2006). When tested with the Head-Toes-Knees-Shoulders tasks, Chinese children outperformed U.S. children on inhibition tasks (i.e., the ability to withhold prepotent behavioral and cognitive responses) (Lan et al., 2011). Similarly, Japanese students outperformed Canadian students in both accuracy and response time when asked to change sorting rules (Imada et al., 2013). One possible explanation for this pattern of cultural variation is differences between children's learning environments and effects of preschool training on cognitive flexibility tasks. For example, urban preschool children in China tend to receive consistent, high-demand training of rule following and self-regulation (Chen et al., 1998; Lan et al., 2009).

Previous cross-cultural research on cognitive flexibility has been limited to comparing Western children and East Asian children. In the extant research, most participants from any of the populations are drawn from relatively educated, urban or suburban, middle class backgrounds. Notably, nearly all previously studied populations tested for early cognitive flexibility have been from educated middle class backgrounds. It is therefore unclear whether experiential factors predicted by educational background and other correlates of socio-economic status (SES) have an effect on cognitive flexibility. In a meta-analysis of studies testing the relation between SES and executive functioning test performance in children (Lawson, et al., 2014), a consistent small-to-medium effect size was found, suggesting that greater SES-associated resources (e.g., parental and educational resources) weakly but reliably predict earlier development of executive functioning skills. Further analyses revealed that the correlation with executive functioning measures was

strongest for attention shifting tests, which were defined to include rule-switching tests (most commonly the DCCS). Although the analysis did not investigate factors such as parental education or language background, it suggests that children with more experience with formal schooling-like activities and materials tend to perform better on the cognitive flexibility tasks.

Current study

The objective of the current study was to examine performance on two tests of cognitive flexibility in populations of children with different preparatory experience with formal education-relevant activities: a middle class sample of English-speaking, U.S. children and a low-income sample of Tswana-speaking, South African children. The South African children had markedly less exposure to pre-kindergarten pre-literacy activities and curricula. Our goal in comparing these two populations was to investigate whether age-related gains in flexibility, documented almost exclusively in Western, Educated, Industrialized, Rich, Democratic (WEIRD) (Henrich, Heine, & Norenzayan, 2010) children using only one (school-like) test of flexibility, are *general* across tasks and populations, or whether they are *specific* to certain culture-specific early school-relevant experiences.

We selected two tests of cognitive flexibility that may tap into different skills related to distinct developmental tasks of children aged 3 to 5 years. In the Flexible Induction of Meaning (FIM) task (Deák, 2000), children must use several *linguistic cues* (ex. phrase: "lives in a") to infer meanings of new words uttered by an adult. In the Dimensional Card Change Sort Task (DCCS) (Zelazo et al., 1996) children must follow changing rules to sort cards in different ways. Both tests tap into a general demand of language processing: to update representations of a speaker's meaning by encoding and processing a 'landscape' of variable and changing cues. Therefore, both tests assess the ability to adapt meaning-representations to changing cues. However the variety and

forms of cues, kinds of generalization, and response types differ considerably. For example, in the DCCS rules and switches are arbitrary, so the test focuses on predicate logic judgments that might depend on experience with formal school-like activities.

We compared the performance of 3- to 5-year-old Tswana-speaking South African children and English-speaking U.S. children on two cognitive flexibility tests (within-subjects): the FIM-Animates word-learning test, and a rule-switching test matched for complexity, the 3DCCS (Blackwell, Chatham, Wiseheart, & Munakata, 2014; Deák, 2004; Deák & Wiseheart, 2015). We also tested children's phonological working memory span, in order to estimate the possible contribution of a cognitive trait that varies across children and that predicts developing verbal skills (Alloway, 2007; Alloway et al. 2008; Gathercole, 2006; Holmes et al., 2014). Within this design we examined age differences within and between populations, and between tasks. Based on previous research with U.S. children we predicted similar age-related changes in word-learning flexibility and in rule-switching flexibility (Deák & Wiseheart, 2015). However, based on differences in experience and resources related to formal pre-school activities between our U.S. and South African samples we predicted less cross-cultural similarity on the rule-switching test (which should favor U.S. children with more preschool experience) than on the word-learning test (which should show comparable performance across populations).

Because the cross-cultural samples differ on multiple dimensions, we considered one additional factor that might influence performance: cross-linguistic differences in the relative difficulty of verbal cues or rules. Prior evidence relatedly show that it is harder for children to switch from an easy to a harder rule or cue, than to switch from a hard to an easier rule/cue (Deák, Ray, & Pick, 2004; Ellefson, Shapiro, & Chater, 2006; Monsell, Yeung, & Azuma, 2000). Previous studies also show that the relative strength of a rule or cue explains order effects in English-

speaking children (Deák, 2004; Deák & Narasimham, 2014; Perner & Lang, 2002). The current study provides an opportunity to determine whether such effects are language specific (i.e., based on the semantics of various cues) or general (e.g., based on some culture-independent difference in the conceptual difficulty of different properties). If cue/rule-strength drives order effects, and cue/rule-strength is language-specific, then order effects might not generalize from English- to Tswana-speaking children. However, if order effects are due to general conceptual biases (e.g., *species* is a more intuitive basis for biological generalizations than habitat; Gelman & Wellman, 1991), then order effects might generalize across language and cultural groups.

Method

Participants

Children were recruited and tested in communities in the U.S. and South Africa. All procedures in both countries were approved by university IRBs and local school administrators. The U.S. sample included 60 preschool children from 36 to 70 months of age (mean = 53 mo; the entire range was uniformly represented). Children were recruited and tested at non-subsidized preschools in majority English-speaking, high socioeconomic status neighborhoods in San Diego county, California. All children were primarily English-speaking, and their teachers verified that there were no known cognitive, language, sensory, or developmental disabilities. The sites where children were tested were licensed preschools with low teacher-child ratios, teachers with high school or college degrees, and classrooms with ample text materials (books, workbooks, instructional materials), symbolic and representational toys, other manipulatives for fantasy and pretend play, and formal games that require reasoning about symbolic mappings. Teacher-lead activities often involved instructed use of manipulatives and symbolic materials in novel ways.

Children's spontaneous symbolic or text-related verbal efforts were, by school policy, reinforced and encouraged.

The South African sample included 60 Tswana-speaking preschool-aged children ranging from 36 to 73 months of age (mean = 53 mo; the entire range was uniformly represented). Children were recruited from a multilingual, low-SES community in a peri-urban informal settlement outside of Johannesburg in Gauteng, South Africa. Schooling in Gauteng is mandatory from 7 and 15 years, but official figures (from 1996) estimate that 11% of Black South African children in this age range are not attending school, and only 23% of 5-year-olds attend preschool. The Gauteng township where children were recruited is very low income. Unemployment rates are high, and families have limited access to resources, educational and otherwise. Children have very little access to books, toys, or preschool-educational materials, either at their homes or at the daycare. All children in the settlement were fluent speakers of Tswana (also known as Setswana), a Bantu language of the Niger-Congo language family, and an official language of South Africa and Botswana. Tasks were translated into Tswana, and back-translated to check accuracy. Research assistants were fluent in English and Tswana. The first author of the paper was present for all data collection in South Africa and the U.S., to ensure procedural consistency.

Materials and Procedures

Each preschool child was tested individually, over two sessions within one week, in a room in their preschool or daycare with distractions minimized as much as possible. The flexibility tests were administered on different days. Children were randomly assigned to rule/cue orders (constrained for equal numbers per order in each of three age strata). Order of flexibility and WM tests was counterbalanced.

Flexible Induction of Meaning (FIM) - Animates Test. In this test children are required to infer meanings of several words for a stimulus array, based on changing sentence-level cues that imply different stimulus properties (Deák, 2000; Deák & Narasimham, 2014). The stimuli include six sets of five complex color-printed and laminated pictures. Each 15x12.5 cm card shows a novel creature in an unfamiliar habitat, holding some distinctive object. Each set includes a 'standard' and four comparison pictures. Three of the comparison pictures each share one property with the standard: the species, the habitat, or the held object. The fourth comparison picture is a distractor that differs in all three properties. An example set is shown in Figure 1.

Children completed three blocks of six trials, with one trial per set per block. Before each trial of the first block children were encouraged to examine the pictures for several seconds. The experimenter then pointed to the standard picture and told the child a fact about it. Every fact incorporated one of three predicate cues: "is a," which (to English speakers) implies the creature's species; "lives [in/on] a," which implies the habitat, or "holds a," which implies the held object. Each cue was followed by a different novel word (see Table 1). After repeating the fact (e.g., "This lives in an *oni*."), the experimenter asked the child to generalize the word to a comparison picture (e.g., "Which of these others also lives in an *oni*?"). Children's responses were untimed, and the experimenter repeated the fact and question again if necessary. The experimenter did not give specific feedback but made the same mildly encouraging comment after every response ("Great, let's look at some more"). Card sets order was randomized for each child and the order was repeated in each block. Card positions were randomized on every trial.

Children were randomly assigned to a *hard* or an *easy* order, determined by results from English-speaking children and therefore only hypothetically harder or easier for Tswana-speaking children. Children assigned to the hard order responded to the cue *is a* [or *ke solo*] in the first block

of trials, *holds a* [*le leng*] in the second block, and *lives* [*in/on*] *a* [*tshela mo*] in the third block. Children in the easy condition responded to *lives* [*in/on*] *a* [*tshela mo*] in the first block, *holds a* [*le leng*] in the second block, and *is a* [*ke solo*] in the third block.

Translation. The first author (CL) collaborated with native Tswana-speaking educators who were familiar with the research protocols and with the children in Gauteng to develop translations of the task protocol and the cues, as well as lists of novel words that would sound natural to the children but dissimilar to known words. The protocols and materials were back-translated by different fluent bilingual adults to verify accuracy.

Three Dimensional Card Change Sort (3DCCS) test. Children are asked to switch between three superordinate rules for sorting and re-sorting cards according to three dimensions: animal type, color and size. Animal types are birds, fish and dogs; colors are yellow, red and blue; and sizes are small, medium and large. As in the FIM-An, children complete three blocks of trials, one per rule, by sorting the same six test cards, once per block. On each trial, children sort a test card into one of four boxes, each with a different target card. For example, in Figure 2 the test card (medium red dog) should be placed in the small-blue-dog box during the animal-rule block, the large-red-bird box during the color-rule block, and the medium-yellow-fish box during the size-rule block. The fourth box (snake) is a distractor to check children's attentiveness and comprehension, and to match the number of response options in the FIM. Each value of each dimension appears on two test cards, but any two values are never combined twice in the test cards seen by a given child. Test card order was randomized for each child; that order was repeated in each block. Box position was randomized on every trial.

The experimenter first checked children's comprehension of the property labels by showing examples and asking children both to label the values of practice cards (e.g., "What animal is

this?"), and to identify labeled practice cards (e.g., "Can you point to the yellow one?"). After the child showed that they could correctly label and identify all properties, the experimenter placed the boxes with standard cards in front of the child and began the test.

In each block, children were first told the current rule; for example, "In the animal game, all dogs go here, all birds go here, and all fishes go here" while pointing to the relevant boxes. Then children were asked to sort each card into a box, one at a time, after hearing the picture labeled. After each trial, children received the same non-conditional feedback as in the FIM-An. After the first and second block, the experimenter reorganized the boxes on the table and gave the next instructions (e.g., "Now we are going to play the color game..." etc.). Children were randomly assigned to one of two order conditions: *hard* or *easy*, based on results from English-speaking children (therefore only hypothetically easy or hard for Tswana-speaking children). The hard order was animal, color, and size. The easy order was size, color, and animal.

Verbal Working Memory (WM). WM span was assessed for words and non-words (Alloway, 2007; Alloway et al. 2008; Gathercole, 2006; Holmes et al., 2014). Items are shown in Table 2. The familiar-word lists included easy-to-pronounce words that would be familiar to a preschooler with normal-range vocabulary for a 3-year-old fluent in the language. Words were randomly divided into lists of four (English) or six (Tswana) words, plus two practice lists of two words each. Non-words were constructed in each language to be easy to pronounce, distinctive, and not readily confused with real words.

Similar to Gathercole's (2006) and Alloway's (2007) procedures, the experimenter explained that after she read the words (or non-words) and said "go," the child should repeat back as many words (or non-words) as the child could remember. After completing practice lists with feedback as needed, the experimenter read each list of words, at a constant rate of 0.75 sec/item

followed by the go-cue. If a child paused for more than 2 sec, the experimenter prompted them to try to remember more. All of the child's productions were recorded, and later independently coded (and verified by a senior author) for accuracy. Productions received 1 point for correct repetition, or 0.5 points for a production that differed by a single phoneme. A 30 sec break was taken after each list, to reduce proactive interference.

Results

Gender effects. Preliminary analyses indicated no gender effects. A 2 (gender) X 2 (country) ANOVA on the main measure from each test found no significant effect and only a marginal interaction with WM_{word}, $F(1,110) = 3.8, p=.055$. Because two marginal results would be expected in 21 p tests, and because the trend does not qualify our hypotheses, boys and girls are combined in all further analyses.

FIM-An. Word-learning flexibility was evaluated by entering the CORSWOPS ratio for each child in a 2 X 2 ANCOVA, with country (South Africa or United States) and cue order (hard or easy) between subjects, and age entered as a covariate. There was a significant effect of age, $F(1,112)=27.5, p<.001, \eta^2_{part}=.197$, but no significant effect of country ($F<1$) (see Figure 3). There was also no significant effect of order, $F(1,112)=2.5, p=.116$. CORSWOPS averaged 0.51 ($SD=0.44$) for U.S. children and 0.47 ($SD=0.27$) for South African children, and averaged 0.56 ($SD=0.35$) in the easy order and 0.42 ($SD=0.37$) in the hard order.

A significant interaction between country and order, $F(1,105)=8.8, p=.004, \eta^2_{part}=.073$, is illustrated in Figure 4. U.S. children, as predicted, were less flexible when switching from the stronger (*is a*) to the weaker (*lives-in [a]*) cue than vice versa: CORSWOPS[−] = 0.36 ($SD=0.42$) vs. 0.67 ($SD=0.41$). However, South African children showed no order effect, CORSWOPS[−] = 0.49 ($SD=0.31$) vs. 0.45 ($SD=0.25$). This supports the speculation (Deák, 2004) that relative

semantic strength of various cues, which affects the difficulty of shifting cue-based inferences, is somewhat language-specific.

To test whether age differences in flexibility differed between countries, the slopes of CORSWOPS across age were compared for the U.S. vs. South African children by a linear regression analysis. First-order statistics show that the correlation between age and CORSWOPS is similar for U.S. ($r = 0.485$) and South African ($r=0.412$) children. The regression indicates that the slopes did not reliably differ between samples: $\beta=0.01$ ($SE=.006$), $t(113)=1.5$, $p=.135$.

3DCCS. Rule-switching flexibility was tested by entering CORSWOPS ratios for each child into a 2 X 2 ANCOVA, with country (S.A. or U.S.) and rule order (hard or easy) between subjects, and age entered as a covariate (see Figure 5). The results showed a significant age effect, $F(1,119)=8.8$, $p=.004$, $\eta^2_{part}=.069$, and a significant country effect, $F(1,119)=14.9$, $p<.001$, $\eta^2_{part}=.111$. South African children's CORSWOPS were lower (mean=0.36; $SD=0.32$) than U.S. children's (0.60, $SD=0.42$). The order effect was non-significant ($F<1$), as was the interaction ($F<1$): U.S. children's averaged 0.62 and 0.58 for the easy and hard orders, respectively, versus 0.38 and 0.34 for South African children.

To test whether age differences in flexibility were larger in U.S. than South African children, the slopes of CORSWOPS by age for U.S. and S.A. groups were compared in another linear regression. First-order statistics show a moderately high correlation between age and CORSWOPS in U.S. children ($r = 0.546$), but no relation in S.A. children ($r=0.027$). The difference between slopes is significant in the linear regression model: $\beta = 0.023$ ($SE=.007$), $t(116)=3.4$, $p=.001$. The U.S. sample showed a positive association between age and rule-switching flexibility, as in previous studies, whereas the S.A. sample showed a flatter function with non-reliable age-related differences.

Flexibility test differences. Flexibility on the two tests was compared by calculating each child's between-test flexibility difference, defined as $[CORSWOPS_{FIM} - CORSWOPS_{3DCCS}]$. Because we did not predict that one test would be more difficult overall, the direction of the difference is arbitrary. A between-group difference would indicate that the two tests differ in difficulty between the two groups. Differences averaged -0.09 for U.S. children ($SD=0.42$) and +0.10 for South African children ($SD=0.35$): a 19% difference in relative test difficulty. This is consistent with the prediction that the 3DCCS would be relatively harder for South African children. To test this pattern and its relation to age, a univariate GLM test compared difference scores, with nationality between-subjects and age as a covariate. The nationality effect was significant, $F(1,117)=6.8$, $p=.010$, but the age covariate was not ($F(1,117)=1.9$, $p=.171$). The difference score for the entire sample was not different than zero ($t(119)<1$), confirming that the tests were similar in difficulty across the entire sample, though differentially difficult for U.S. and S.A. children.

Verbal working memory. Verbal working memory (vWM) was assessed separately for words and non-words, in each country. U.S. children recalled a mean total of 5.0 (out of 8) familiar words; $SD=2.4$, and South African children recalled 5.9 (out of 12); $SD=1.5$. For non-words, U.S. children recalled an average of 3.3 (out of 8); $SD=1.9$, and S.A. children recalled 2.9 (out of 12); $SD=1.8$. Total words recalled were calculated by adding up both trials of a given list-type, including half-point scores, not including practice trials. One U.S. and three South African children did not complete the non-word WM test; statistics were calculated for the remaining 116 children. Although we cannot compare raw scores between countries because the tests were not normed or standardized across languages or populations, it is clear that the S.A. children performed better or

at least as well as the U.S. children, considering that the former had longer words and lists (in order to minimize ceiling effects and to maintain typical phonological properties of Tswana words).

Exploratory analyses revealed that combining total word and non-word recall yielded a more stable overall vWM estimate. This combined score does not obscure any differential correlations with either group or test variables. Therefore, to limit the number of tests, further analyses consider only this total (words+non-words) recall score. Additionally, because recall scores were language-specific and un-normed, they were standardized for each group. These z-scores, $WM_{total-std}$, were correlated with age in the U.S. sample, $r(59)=0.49$, $p<.001$, but uncorrelated with age in the S.A. sample, $r(57)=-0.04$.

Predicting flexibility: Age, vWM, and culture. We next tested whether variance in flexibility was predicted by verbal WM as well as age, and whether flexibility remained differentially affected by cultural experience (alone, or modulated by cue/rule order) when both age and vWM span were considered. To reduce test-wise inflation of Type I error, a criterion of $\alpha \leq .025$ was adopted. For FIM-An CORSWOPS (i.e., word-meaning flexibility) scores, age and $WM_{total-std}$ scores were entered in the first two steps of a regression. Cue order was entered in the third step, and country of origin in the fourth step. Age, in the first step, was a significant predictor, $F(1,114)=31.6$, $p<.001$, $R^2=.217$. WM recall predicted marginal additional variance in the second model, $\Delta R^2=.032$, $F_{\Delta}(1,113)=11.2$, $p_{\Delta F}=.030$. Cue order predicted a marginally significant proportion of variance in the third step, $\Delta R^2=.027$, $F_{\Delta}(1,112)=3.7$, $p_{\Delta F}=.045$. In the last step, country of origin did not explain additional variance: $\Delta R^2=.003$, $F_{\Delta}(1,111)<1$. Beta weights of the models are shown in Table 3 (top). As a check of the robustness of the solution, several modified regressions were run with different vWM measures and entry models. All yielded the same results.

For 3DCCS CORSWOPS, an analogous regression showed that age (first step) was a significant predictor, $t=3.1, p<.003, R^2_{adj}=.104$. WM_{total-std} predicted significant additional variance in the second step, $\Delta R^2=.074, F_{\Delta}(1,113)=10.3, p_{\Delta F}=.002$. Rule order did not predict significant variance in the third step, $\Delta R^2=.005, F_{\Delta}(1,112)<1$, but in the final model, country predicted significant additional variance: $\Delta R^2=.069, F_{\Delta}(1,111)=10.3, p_{\Delta F}=.002$. Beta weights are shown in Table 3 (bottom). To check robustness, several modified regressions were run with different vWM measures and entry models. All yielded the same results.

These results confirm and extend the previous analyses by showing that with age, vWM, and cue/rule order accounted for, there were no reliable cross-cultural differences in FIM-An overall flexibility, but there were significant differences in the 3DCCS.

Discussion

Young children attending preschools in industrialized countries show age-related improvement in cognitive flexibility. It is unclear, however, whether flexibility is a coherent, unitary cognitive trait that develops similarly across populations, or is an emergent dimension of task-specific performance that varies across populations with different educational experiences (Ionescu, 2017). To examine the impact of pre-formal education experiences on the development of cognitive flexibility, we compared U.S. and South African children's performance on two distinct tests of cognitive flexibility, matched for complexity. Our data suggest that cognitive flexibility is not exclusively an age-dependent cognitive trait, but instead, is influenced by particular kinds of educational experiences. Controlling for working memory, children from both populations performed similarly on the word-learning test (FIM-Animates), showing a predicted age-related trend. In contrast, only U.S. preschoolers showed an age-related increase in flexibility on the rule-switching task (3DCCS).

If South African children performed significantly differently from U.S. children on both the flexible induction of word meaning task and the test of rule-use flexibility, it would be difficult to disentangle those results from pervasive between-group differences such as language differences, the greater novelty of the testing situation for the South African children, significantly fewer family, school and community resources, and other SES-related challenges (including multiple developmental risk factors) for the South African children. However, because the South African children performed comparably to the U.S. children on the inductive task, and indeed on the verbal working memory measures, but *not* above chance on the deductive task, it is possible to explain the cross-cultural difference in terms of more specific factors, perhaps including differential experience with demands to follow discrete, arbitrary rules. That is, preschool children in U.S. schools have more exposure to explicit, rule-like instructions that involve symbolic or arbitrary mappings (e.g., board games), and those experiences might play a causal role in (what have been thought of as universal) age-related changes in arbitrary rule-switching tasks.

These results are consistent with other evidence that exposure to educational cultural practices and tools, including literacy, can induce different modes of reasoning (e.g., syllogistic deductive inference), and so some apparent age-related differences in reasoning and thinking are, in fact, differences in exposure to cognitive models and processes that are propagated by education systems (e.g., Harris, 2001; Luria, 1976; Olson, 1977). The current results suggest that adherence to abstract and arbitrary rules is in and of itself (independent of the difficulty of each particular rule), a skill that is learned via some sort of experience that is more common among young children who are being groomed to spend many days per year in educational environments that focus on symbol manipulation and symbolic reasoning.

The results also support and extend previous findings that verbal working memory plays a moderating role in children's performance. This is consistent with previous research, using converging measures, that preschool-age children's working memory function for maintaining task or cue information predicts some variance in task-switching accuracy and/or speed (Chevalier, Sheffield, Nelson, Clark, Wiebe, & Espy, 2012; Marcovitch, Boseovski, Knapp, & Kane, 2010; Holt & Deák, 2015). In the current study, verbal working memory as measured by word and non-word span was positively associated with flexibility in word-meaning as well as rule-switching flexibility tests, although it was only a modest mediator variable (~3-7% of unique variance). Its modest contribution might explain why Deák and Wiseheart (2015) found no association (when age was partialled out) between either test of flexibility and another test of verbal working memory, the Memory for Names test from the Woodcock-Johnson battery. That test, however, involves more than verbal working memory, because participants must learn and recall novel associations between novel words and novel pictures; thus it involves visual memory and associative learning as well as verbal working memory. Other factors might influence the relation between flexibility and verbal working memory; for example, Chevalier et al (2012) found the association to be reliable among older preschoolers (4-5 years) but not younger preschoolers (3 years). Thus, there are certainly outstanding questions about the manner in which verbal working memory differences contribute to variability in young children's flexibility.

The two groups did not show similar task order effects, which is consistent with the hypothesis (Deák, 2004) that relative task difficulty is a function of the semantic strength of specific cues for a given task, and this strength will be language-specific. That is, following the generalization that people show greater switch costs when switching from an easier to a harder test than vice versa (e.g., Deák et al., 2004; Ellefson et al, 2006), children might show lower flexibility

when switching from an easier sorting rule or semantic cue to a harder one. This has been found in English-learning, U.S. preschoolers for both the FIM-An and the 3DCCS (e.g., Deák & Narasimham, 2014; Deák & Wiseheart, 2015). However, in the current study only U.S. children, but not South African children, showed an order effect on the FIM-An. This suggests that order effects are based on specific cue strength, and in the case of verbal cues, semantic association strength will be language-specific. Conversely, the results do not support the possibility that some features (e.g., shape or species) are simply more "basic" or "natural" than others for inductive or sorting generalizations, among children from a wide range of cultural or linguistic backgrounds. In short, it is linguistic transparency, not conceptual availability, that "drives" difficulty of particular tasks or trial types.

Given substantial evidence that rule-switching tasks, and other measures of cognitive flexibility and executive function strongly predict academic achievement, the lack of exposure to preschool curriculum with relevant experience could put children at an educational disadvantage. Future research should examine the impact of particular kinds of preschool experience on cognitive developmental outcomes. Research comparing children who attend preschools with more extensive rule-use instruction than others should be conducted to examine and explain both individual and group differences in performance on cognitive flexibility tasks.

Research with multiple tasks, matched for complexity, is critical for understanding age, individual, and cultural differences in cognitive tasks. Extensive reliance on single tasks, a pervasive practice within the cognitive developmental literature, provides insufficient insight into the development of complex cognitive capacities that are influenced by cultural input and experience. Data from two tasks of cognitive flexibility do not support the proposal that cognitive flexibility is a unitary, experience-independent trait. Our results are consistent with the

proposal that rule-switching skill is more dependent upon exposure to school-preparatory activities involving symbolic and arbitrary rules than word learning.

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Table 1: Novel words used in English and Tswana FIM-An Test

Cue Semantics	Implies Species	Implies Possessed Object	Implies Habitat
English Cue	<i>is a...</i>	<i>holds a...</i>	<i>lives in a...</i>
English Novel words	leddy finnel brine ickus simee necker	minnar rett kumo dobe paydoo zyloh	toma snape volat abbick crone oni
Tswana Cue	<i>ke selo...</i>	<i>le leng...</i>	<i>tshela mo</i>
Tswana Novel words	motshelo mekgato lenong phadisano lewatle hlalosa	khudu kgokgotso anyisa goikatlisa mofufutso lefaru	sekerefolo seyalemoya malele lefaufau mosima maungo

Table 2: English and Tswana words and non-words (Working Memory test)

	English Words	English Non-words	Tswana Words	Tswana Non-words
Practice	fire box	mogul jicker	mma letsogo	khurumo tladu
Practice	apple cup	nafad cam	merogo molala	leri leturi
Trial 1	peg dirt forest rug	froop kib maitai deelo	letsatsi leihlo tsela leleme marapo lélao	dilese legora lamotha mahu thoru tselo
Trial 2	muffin daisy feet table	bade geck sote chibe	tsebe lebese molomo pudi ngwana ntsa	gwai mapase kabolo mokatari mphaphathi matoto

Table 3: Weights of step-wise regressions CORSWOPS in the FIM-An test (top) and the 3DCCS test (bottom), with (1) age, (2) vWM_{total-std}, (2) cue/rule order, and (3) country, in that order.

PREDICTOR	β	SE	β (standardized)	t	p
<i>FIM-AN</i>					
1. Age	.016	.003	.400	4.78	<.001
2. vWM	.073	.030	.199	2.39	.019
3. Order	.122	.059	.168	2.06	.042
4. Country	-.040	.059	-.055	-0.68	<i>ns</i>
<i>3DCCS</i>					
1. Age	.011	.003	.261	3.10	<.001
2. vWM	.108	.032	.283	3.36	.002
3. Order	.035	.062	.047	0.57	<i>ns</i>
4. Country	-.200	.062	-.263	-3.21	.002

Figure 1: Example of a stimulus set in the FIM-An task.

Figure 2: Example of a test card (top) and target cards (bottom) in the 3DCCS. The test card should be sorted into a different target box for each rule (see text).

Figure 3: Scatterplot of FIM-An flexibility scores (CORSWOPS, or proportion of correct switches), by age, for U.S. and South African children. Regression lines show linear solutions, with mean confidence intervals (95%). R^2 values are indicated in the legend.

Figure 4: Box plot of FIM-An CORSWOPS (proportion of correct switches) by cue order (hard/*is a*-first vs. easy/*lives in*-first) in U.S. and South African children.

Figure 5: Scatterplot of 3DCCS flexibility scores (CORSWOPS, or proportion of correct switches), by age, for U.S. and South African children. Regression lines show linear solutions, with mean confidence intervals (95%). R^2 values are indicated in the legend.