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Exploring the Foundations of Early Scientific Literacy: Children's Causal Stance

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Abstract

From an early age, children show a keen interest in discovering the causal structure of the world around them. Given how fundamental causal information is to scientific inquiry and knowledge, this early emerging “causal stance” might be important in propelling the development of scientific literacy. However, currently little is known about the development of children’s causal stance, or how it might relate to concurrent or subsequent scientific literacy. In this study, 153 children from diverse backgrounds were evaluated at 3, 4, 5, and 6 years of age. Results demonstrate that causal stance at 3 years of age consistently predicted scientific literacy at each wave of data collection, extending through preschool, kindergarten, and into first grade. This relation was particularly pronounced across the earliest two measurement time-points, when children’s causal stance predicted *growth* in scientific literacy above and beyond initial scores. The reciprocal relation did not hold: scientific literacy did not predict future causal stance. Implications for school readiness and early STEM engagement are discussed.

Keywords: causal stance, scientific literacy, STEM, early childhood, school readiness

Foundations of Early Scientific Literacy: Children's Causal Stance

Coming to understand the world in ways that support effective reasoning, accurate prediction, and adaptive behavior requires keen attunement to causality. Accordingly, perception of physical causality emerges early (Mascalzoni et al., 2013; Oakes & Cohen, 1995), and an extensive literature describes children's rapidly developing abilities to infer causality more broadly from patterns of covariation and the outcomes of active interventions (e.g., Benton et al, 2021; Goddu & Gopnik, 2020; Goddu et al, 2021; Gopnik et al, 2001). Not only are young children capable of perceiving and reasoning about causality, but they appear to have a strong intrinsic motivation to acquire causal understanding of the world around them. Although the evidence base regarding this 'causal stance' is small, it can be observed in children's preferential exploration of objects that have an either ambiguous or surprising causal structure (Schulz & Bonawitz, 2007; Stahl & Feigenson, 2018), as well as in their inquiry patterns. Preschoolers ask most often about the causally-relevant functional properties of artifacts (Kemler Nelson et al., 2004) and are most satisfied by answers that provide plausible causal explanations thereof (Asher & Kemler Nelson, 2008).

In their more recent investigations of children's causal stance, [MASKED REFERENCE 1] demonstrated that preschoolers were more motivated to complete a boring task when rewarded with causally-rich descriptions of novel objects, than when rewarded with causally-weak descriptions. When these types of descriptions were directly pitted against each other in a forced-choice task, children overwhelmingly chose to hear the causal descriptions ([MASKED REFERENCE 2]), and the degree to which individual children did so was related to their inclination to ask causally-relevant questions about novel items (MASKED REFERENCE 3). Notably, these individual differences in the degree to which 4-year-olds preferred and inquired

about the causal properties of novel items were relatively stable over a one-month delay (MASKED REFERENCE 3).

Although not the primary focus of their report, [MASKED REFERENCE 4] also noted a significant correlation between the strength of children's causal stance and their scientific literacy at 3 years of age (also see Fusaro & Smith, 2018). This association makes intuitive sense: given the centrality of causal information to scientific knowledge and reasoning, it stands to reason that a heightened attunement to causality would support development in this domain. Indeed, "cause and effect" is highlighted as a key cross-cutting concept in the Next Generation Science Standards (National Research Council [NRC], 2013), as well as the *Framework for K-12 Science Education* (NRC, 2012), both of which were developed to guide and foster science learning in school.

That said, linkages between children's attunement to causality and their scientific literacy have thus far only been demonstrated in the context of contemporaneous measurement of the relevant constructs. As a result, we cannot yet be certain of the directionality of this association. Although attunement to causal information might support the development of scientific literacy by drawing attention to the mechanisms underlying natural phenomenon, it is also possible that knowledge of, and ability to reason about, these fundamental mechanisms support a greater appreciation of their value and importance. Consistent with this latter possibility, substantial literature demonstrates that domain-specific theories that encompass scientific concepts and causal mechanisms can guide children's attention and information-seeking behaviors (e.g., Greif et al, 2006; Kominsky et al, 2017; Wellman & Gelman, 1992).

To clarify the association between children's causal stance and scientific literacy, and to assess developmental effects, a longitudinal lens is required. In the current work we therefore

extended the analysis presented in [MASKED REFERENCE 4] to include three additional annual waves of data collection with the same group of children. We ask specifically whether the strength of children's causal stance at 3 years of age predicts their subsequent scientific literacy at mean ages of 4, 5, and 6 years. We further consider whether children's causal stance measured in subsequent years is also related to contemporaneous and subsequent scientific literacy.

Method

Transparency and Openness

All data, analysis code, and research materials are available at [stable link to repository]. Data were analyzed using SPSS (version 27). This study's design and its analyses were not preregistered, but the design and predictions were specified a priori in a National Science Foundation grant proposal ([MASKED]). This project was approved by the University's Institutional Review Board (Study #171030).

Participants

The 153, 3-year-olds described in [MASKED REFERENCE 4] were tracked longitudinally for three additional years in the current study. At first follow-up, 120 children (64 females, $M_{\text{age}} = 4.59$, $SD = .26$, range = 3.66 – 5.09) remained in the study, at second follow-up, 112 (61 females, $M_{\text{age}} = 5.02$, $SD = .23$, range = 5.02 – 5.92) remained, and at the third follow-up 88 (43 females, $M_{\text{age}} = 6.78$, $SD = .23$, range = 6.04 – 7.66) remained. Demographic information is presented in Table 1. Throughout these three additional years of assessment, attrition was primarily due to families moving out of town or our inability to re-establish contact. Data collection at the final measurement time-point was also substantially disrupted by the COVID-19 pandemic, resulting in a spike in attrition and an eventual shift to virtual data collection.

Procedure

Data for this study were collected across a total of nine sessions, three sessions at the first measurement wave, and two sessions in each subsequent wave. Each session lasted approximately 30-60 minutes. The average time window in which the sessions were completed at each wave was 4.89 months ($SD = 2.53$) at 3 years, 1.62 months ($SD = .79$) at 4 years, 1.35 months ($SD = 1.15$) at 5 years, and .92 months ($SD = 1.67$) at 6 years. All but the first session of the first wave of data collection, which was run at a local children's museum, were scheduled to take place in the laboratory. However, for approximately one quarter of the final wave participants, the tasks had to be adapted to an online format for remote data collection. Within each wave, tasks were conducted in a fixed order. Sessions were audio-visually recorded for offline coding of participant responses and verification of protocol fidelity.

Measures and Stimuli

Measuring Causal Stance.

The strength of children's causal stance was measured using the following three tasks, all of which were administered at all waves of data collection, with the one exception noted below. All causal stance tasks were video-recorded to facilitate coding. Additional details regarding procedures, stimuli, and coding can be found as Supplemental Materials and in [MASKED REFERENCE 4].

Causal Preference. This task consisted of 10 trials, on each of which the child viewed a novel animal or artifact (which had an interesting physical feature obscured by a red button) on a touch-screen computer. On each trial, children could choose to press either the rectangular button to see the hidden part, or press a round button at the bottom of the screen to hear a pre-recorded causally relevant description of the item (e.g., "This one rattles its tail to scare other animals

away!”). Children indicated their choice on each trial verbally and/or by touching one of the buttons. This task was scored as the proportion of trials for which children chose to hear the causal description (instead of seeing the hidden part). All scores were coded from video, with 20% double-coded by a second independent researcher. Because child responses were so easily distinguishable, coders were in 100% agreement.

Novel Picture Inquiry. This task began with the experimenter placing 10 cards, each picturing an unfamiliar artifact (e.g., a motorcycle shock mount), in front of the child. The experimenter asked the child to choose one to learn about, and then prompted the child to ask questions about the selected item (e.g., “What do you want to know about this one?”). The experimenter answered questions produced by the child in an informative, but brief and circumscribed way, according to a prespecified list of responses. When a participant stopped asking questions about the chosen card, the experimenter put the remaining cards back in front of the child, saying “Which do you want to learn about next?,” repeating this procedure until all 10 cards were chosen. This task was scored as the proportion of total questions asked that elicited causal information. To maximize accuracy, two coders independently coded all transcripts for instances of causal and non-causal questions (see Table 2 and [MASKED REFERENCE 2] for additional coding details). Although the initial interclass correlation based on the proportion of questions that elicited causal information was high (.92), discrepancies of greater than 20% for any individual subject were further resolved by discussion. Due to administrative constraints, this task was not included in the 4-year-old wave of data collection.

Novel Object Inquiry. This task was included as a supplement to the novel picture inquiry task, with the thought that more naturalistic play with real objects might elicit more question-asking from our young participants. Children were presented with six unusual objects

simultaneously and were instructed to play with them however they wanted. They were also informed that they could ask the experimenter anything they wanted to know about the objects at any time. Throughout the 10-minute free-play period, the experimenter silently inspected the objects and responded to questions in the same manner as in the novel picture inquiry task. This task was scored as the proportion of total questions asked that elicited causal information.

Coding proceeded in the same manner as described for the novel picture inquiry task. Interclass correlation was .96, with discrepancies again further resolved through discussion. Because this task could not be adapted for virtual data collection during the COVID-19 pandemic, a disproportionately high level of missing data (65%) occurred at the 6-year-old measurement time point.

Measuring Scientific Literacy.

Developmentally appropriate measures of scientific literacy were utilized at each measurement time point. For the earliest two waves, only one standardized measure was available: the Lens on Science (Greenfield, 2015). This adaptive digital assessment targets all elements of early scientific literacy as currently conceived (NRC, 2013; NRC, 2012), including factual disciplinary knowledge, as well as scientific practices and crosscutting concepts. The outcome variable is a continuous item response theory (IRT) ability score ranging from -3 to 3 . At 5 years of age, the Science Learning Assessment (SLA; Samarapungavan et al., 2009) was administered in addition to the Lens on Science. The SLA includes 30 questions focused on the scientific inquiry process (e.g., making predictions, understanding simple scientific tools), as well as life science concepts. At 6 years of age the SLA was supplemented by the standardized science subtest of the TerraNova – Third Edition (CTB, 2010) instead of the Lens on Science,

which was no longer developmentally appropriate. This subtest includes 20 questions that assess core science content areas (life science, earth science, physical science, and scientific inquiry).

Measuring Cognitive Skill.

The National Institute of Health Toolbox (NIH-TB) Early Childhood Cognition Battery (ECB), administered on an iPad, includes adaptive measures of cognitive flexibility, inhibitory control, episodic memory, and receptive vocabulary. The Dimensional Change Card Sort Test (Zelazo et al., 2013) evaluates cognitive flexibility, or the ability to adjust to new tasks and demands. The Flanker Inhibitory Control and Attention Test (Zelazo et al., 2013) assesses children's inhibitory control of visual attention. The Picture Sequence Memory Test assesses children's episodic memory (Bauer, Dikmen, Heaton, Mungas, Slotkin, & Beaumont, 2013). Finally, the Picture Vocabulary Test (Gershon et al., 2013) measures receptive vocabulary. Based on performance on these four tasks, NIH Toolbox Early Childhood Composite Score provides a highly reliable assessment of overall general cognitive functioning in young children. It is computed by averaging the normalized scores of each of the four tasks, then obtaining scale scores based on this new distribution.

Results

Given the necessity of switching to remote data collection during the last wave of data collection, we first conducted a series of t-tests to assess whether children responded in systematically different ways across testing mode. No significant differences were detected (all $ps > .05$). We next assessed patterns of missing data at the initial 3-year-old measurement time point (as reported in [MASKED REFERENCE 4]), as well as additional data lost to attrition over subsequent measurement waves. Little's Test (Little, 1988) was not significant, $\chi^2(991) = 1022.08, p = .240$, indicating that our data were missing completely at random (MCAR) and

therefore did not vary in systematic ways across key demographics or measurements. To address the missing data in a maximally unbiased manner, we conducted 100 iterations of multiple imputation including all of our causal stance and scientific literacy measures, as well as auxiliary variables that both correlated highly ($r > .4$) with our key measures of interest and had no more than 25% missingness themselves (see Johnson & Young, 2011).

Following previous work ([MASKED REFERENCE 3]; [MASKED REFERENCE 4]), we next averaged the causal stance measures available at each wave into a single composite score. For those waves in which more than one measure of scientific literacy was available, these were also standardized and averaged into a single composite score. See Table 3 for means and standard deviations for these measures at each age tested.

To investigate associations between children's causal stance and scientific literacy, we first considered the bivariate correlations between our key variables. As summarized in Table 3, causal stance scores at 3 years of age correlated with scientific literacy at all waves of measurement. Later measures of causal stance failed to show the same pattern of association with contemporaneous or subsequent scientific literacy. Somewhat unexpectedly, causal stance also failed to correlate with itself across any two measurement timepoints, (all $ps > .09$). Little evidence of reciprocal relations between scientific literacy and subsequent causal stance is evident in Table 3. Indeed, the one anomalous correlation observed was between scientific literacy at 4 years of age and causal stance at 6 years. To further clarify the nature of the observed associations, we ran a multivariate regression predicting scientific literacy at each wave of measurement from the strength of children's causal stance at 3 years of age, while controlling for baseline scientific literacy (i.e., at 3 years of age) and cognitive skill. In this analysis, causal stance at 3 years only remained predictive of scientific literacy at 4 years of age (see Table

4). The one reciprocal relation between scientific literacy at 4 years and causal stance at 6 years fell to marginal significance after controlling for causal stance and cognitive skills at 4 years ($p = .051$; see Table 5).

As previously noted, we combined our causal stance scores into a single composite for the planned analyses presented thus far. This decision was based on the face validity of conceptual equivalence across our measures, as well as prior work ([MASKED REFERENCE 3]) indicating a not only a strong correlation between performance on comparable picture inquiry and preference measures of causal stance in preschoolers, but also stability of their composite across a one-month period. However, preliminary analyses revealed that these correlations across tasks and time did not replicate in the current dataset at any age tested, with the exception of the causal preference task at 4 years correlating with itself at 5 years ($r = .35, p = .002$) and 6 years ($r = .29, p = .017$).

To clarify whether the observed relation between children's causal stance and scientific literacy held at a more fine-grained task level, we therefore repeated our analyses for each causal stance measure separately. Inspection of the bivariate correlations in Table 6 reveals that while the preference and object inquiry tasks each correlate weakly with scientific literacy at a single measurement time point, only the picture inquiry task mirrors the consistent pattern of correlation observed for the causal stance composite score. When subject to the more stringent multivariate regression analysis controlling for initial scientific literacy, both picture inquiry and object inquiry at 3 years predicted scientific literacy at 4 years (but not 5 or 6 years; see Table 7). Reciprocal relations were again sparse, although scientific literacy at both 3 and 4 years of age predicted object inquiry scores at 6 years.

Discussion

The primary goal of this investigation was to clarify whether children's early interest in causality might be foundational to their emergent scientific literacy. Specifically, we sought to establish the directionality of a previously reported association between the strength of children's causal stance and their emergent scientific literacy at 3 years of age ([MASKED REFERENCE 4]). By examining key variables longitudinally over 4 years, we discovered that causal stance is indeed predictive of *subsequent* scientific literacy. Remarkably, children's causal stance at 3 years of age consistently predicted scientific literacy at each wave of data collection, extending through preschool, kindergarten, and into first grade. This relation was particularly pronounced across the earliest two measurement time-points, when children's causal stance predicted *growth* in scientific literacy above and beyond initial scores.

Note that, when considered individually, some measures of causal stance were more predictive than others. Although the preference task was related to contemporaneous measurements of scientific literacy at 3 and 4 years of age, only the inquiry tasks were predictive of subsequent scientific literacy. Specifically, both object inquiry and picture inquiry scores at 3 years of age predicted scientific literacy one year later, even after controlling for initial scientific literacy scores. Picture inquiry (albeit not object inquiry) also predicted scientific literacy at 5 and 6 years of age. However, as was the case with the composite causal stance score, these longer-term associations did not hold when controlling for initial scientific literacy. The directionality of these observed relations was further confirmed by the fact that scientific literacy scores at 3 years of age did not predict composite causal stance, causal preference, or picture inquiry scores at 4 years of age. That is, the reciprocal relations did not hold. Scientific literacy at 3 and 4 years of age did predict object inquiry scores at 6 years of age (and the latter also

predicted the causal stance composite at 6 years – although only marginally so) suggesting the possibility of a “sleeping effect” in this alternative direction. However, it is difficult to generate a coherent explanation for why shorter-term effects should not also be observed, or why scientific literacy should predict subsequent object inquiry, but not picture inquiry or preference scores. Moreover, because so much of the 6-year-old object inquiry data had to be imputed due to pandemic-related disruption, effects specific to this variable need to be interpreted with some caution.

The generally stronger predictive power of the inquiry tasks might be attributed in part to the greater ecological validity afforded by their open-response format, relative to the forced-choice structure of the preference task. It might also be that children’s pattern of question-asking is particularly relevant to the development of their scientific literacy. Effective question-asking is essential to knowledge acquisition across domains, and specifically targeting causal information therein is particularly revealing about the concepts and mechanisms at the heart of scientific knowledge (Butler, 2020; Chouinard et al., 2007; Mills et al., 2019). Moreover, seeking causal explanation and understanding in this manner is often construed as a key component of the scientific inquiry process in and of itself (Jirout & Zimmerman, 2015; NRC, 2013; Schwarz et al., 2017). Future research with a broader range of tasks, perhaps including even more naturalistic observations of children’s propensity towards causal-oriented inquiry in everyday settings (e.g., bath-time), will be necessary to clarify this point.

Regardless of which causal stance tasks are under consideration, only the earliest measurements, taken when children were 3 years of age, were predictive of concurrent or subsequent scientific literacy. One possibility is that this is an artifact of measurement limitations. Although the validity and stability of two of our causal stance measures (causal

preference and picture inquiry) was established in Alvarez and Booth (2016), the children sampled for that work were closest in age to those in the current project at the first (3-year-old) wave of data collection. The psychometric properties of these (and the object inquiry) tasks have not been established for older children, and thus might not be as accurate or precise as we had hoped. The lack of correlation observed across sessions is consistent with this possibility.

Nonetheless, it is also possible that the measurements remain strong as children age, but that children's causal stance changes developmentally in ways that decouple it from their scientific literacy. It might be, for example, that our earliest measurement most purely reflects children's initial attunement to causality because it predates the potential shaping influence of formal learning environments. Once children enter preschool, as all participants in the current study did within 2 months of their initial enrollment, exposure to a wider range of experiences and attitudes might begin to affect their intrinsic interest in causality and/or their scientific literacy. With respect to the former, it is interesting that causal stance scores increase from 3 to 5 years, and then plateau just as children are entering kindergarten (see Table 3). This might be related to other evidence suggesting that intrinsic motivation and curiosity decline as children become accustomed to the structured pedagogy of the classroom (See Engel, 2011; Potvin & Hasni, 2014). It is also notable that the home science environment appears to have a waning association with children's scientific literacy during this same developmental period ([MASKED REFERENCE 5]) as children transition to school. Once school begins to exert a stronger influence on both children's interests and exposure to science, there may be less opportunity for these to influence each other in individual children. This is clearly an area in need of further investigation.

In sum, the current work highlights the potential importance of nurturing children's attunement to causal information prior to school entry. Three-year-olds with a strong causal stance demonstrated faster growth in scientific literacy over the following year, and these relative gains were maintained through first grade. This key finding is consistent with evidence and theory pointing to the importance of motivations, interests, and attitudes to the pursuit of science, and for achievement more generally speaking (e.g., Pattison & Dierking, 2019; Leibham, 2013; Mantzicopoulos, Patrick, & Samarapungavan, 2008). Children who are more strongly driven to seek out causal explanations may be more likely to discover and fully appreciate the causal structure of the world around them, and to enthusiastically apply their causal-reasoning capabilities to scientific endeavors. In this way, a strong 'causal stance' might fuel children's interest in science and propel their acquisition of scientific concepts.

In future work, it will be important to clarify just how malleable the strength of children's early causal stance is, as well as the most effective means for its optimization. Evidence thus far suggests that children's causal stance is related to the frequency with which parents incorporate causally relevant information into their speech ([MASKED REFERENCE 4]). However, the directionality of this association remains to be established, and a broader range of potentially impactful experiences (e.g., exposure to science activities) in formal and informal learning contexts should be explored. Interventions informed by these investigations could ultimately address the poor preparedness of many children for learning science upon school entry (e.g., Bustamante et al., 2018; Curran & Kellogg, 2016; Greenfield et al., 2009; Janus & Duku, 2007) and advance children's broad engagement and success in STEM.

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Table 1

Participant Demographics (in Percentages) Across 4 Years of Data Collection

	3 years (<i>n</i> = 153)	4 years (<i>n</i> = 120)	5 years (<i>n</i> = 112)	6 years (<i>n</i> = 88)
<u>Race</u>				
White / Caucasian	73.9	74.2	78.4	78.4
Black / African American	13.1	12.5	7.2	4.5
Asian / Asian American	2.6	1.7	0.9	2.3
Mixed Race / “Other”	10.5	11.7	13.5	14.8
<u>Ethnicity</u>				
Non-Hispanic/Latino	69.9	72.5	68.5	70.5
Hispanic/Latino	30.1	27.5	31.5	29.5
<u>Maternal Education</u>				
No more than high school	27.5	20.9	18.0	12.5
Technical or Associates degree	6.5	6.7	6.3	6.8
Bachelor’s degree	38.6	44.2	46.8	46.6
Master’s degree	18.9	20.0	19.8	22.7
Advanced degree	8.5	8.3	9.0	11.4

Table 2

Examples of Children’s Causal and Non-Causal Questions

Causal	Non-Causal
What does this do?	What is this one called?
What is this for?	What is it? [†]
What can you do with this?	Is this yours?
How does this work?	

[†] If, after learning the name of the object in response to this question, the child asked again (e.g., “but what is it?”), or otherwise probed further, this second question was considered a causal question.

Table 3

Bivariate Correlations and Descriptive Statistics for Composite Measures of Key Variables

		Causal Stance				CogSkill	<i>M (SD)</i>
		3 years	4 years	5 years	6 years	3 years	
Scientific Literacy [†]	3 years	.39**	.11	.13	.20	.56**	0.36 (1.00)
	4 years	.49**	.19	.19	.25*	.54**	1.58 (0.99)
	5 years	.30*	.20	.15	.19	.42**	0.00 (0.86)
	6 years	.37**	.16	.07	.05	.47**	0.00 (0.86)
CogSkill	3 years	.33**	.22*	.11	.09		
<i>M</i>		0.41	0.58	0.71	0.67	103.87	
<i>(SD)</i>		(0.23)	(0.22)	(0.15)	(0.13)	(14.60)	

Note. CogSkill = NIH toolbox Early Childhood Cognition Battery[†] Scientific Literacy at 5 and 6 years is a standardized composite score but is a single score at 3 and 4 years.** $p < .01$, * $p < .05$

Table 4

Parameter Estimates from Multivariate Regression Analysis (with Composite Variables)

Outcome	Predictor	Unstandardized		Standardized	<i>t</i>	<i>p</i>	95% CI	
		<i>B</i>	<i>SE</i>	β			<i>LL</i>	<i>UL</i>
SciLit (4 years)	Intercept	-0.41	0.52		-0.79	.430	-1.44	0.61
	SciLit (3 years)	0.46	0.08	.46	5.54	< .001	0.30	0.62
	CogSkill (3 years)	0.01	0.01	.20	2.56	.011	0.00	0.02
	CauseStance (3 years)	1.06	0.41	.25	2.59	.010	0.25	1.87
SciLit (5 years)	Intercept	-1.46	0.55		-2.65	.008	-2.55	-0.38
	SciLit (3 years)	0.29	0.09	.34	3.21	.001	0.11	0.46
	CogSkill (3 years)	0.01	0.01	.20	2.10	.036	0.00	0.02
	CauseStance (3 years)	0.38	0.46	.10	0.81	.416	-0.54	1.29
SciLit (6 years)	Intercept	-1.97	0.60		-3.30	< .001	-3.14	-0.80
	SciLit (3 years)	0.22	0.09	.25	2.42	.016	0.04	0.40
	CogSkill (3 years)	0.02	0.01	.26	2.60	.009	0.00	0.03
	CauseStance (3 years)	0.69	0.51	.18	1.35	.178	-0.31	1.69

Note. SciLit = Scientific Literacy (composite score); CogSkill = NIH toolbox Early Childhood Cognition Battery; CauseStance = Causal Stance (composite score); CI = confidence interval; *LL* = lower limit, *UL* = upper limit

Table 5

Parameter Estimates from Linear Regression (Exploring Reciprocal Relationship)

Outcome	Predictor	Unstandardized		Standardized	<i>t</i>	<i>p</i>
		<i>B</i>	<i>SE</i>	β		
CauseStance (6 years)	Constant	0.65	0.12		5.65	<.001
	CogSkill (4 years)	0.00	0.00	-.06	-0.50	.617
	CauseStance (4 years)	0.04	0.08	.07	0.46	.650
	SciLit (4 years)	0.04	0.02	.27	1.96	.051

Note. CogSkill = NIH toolbox Early Childhood Cognition Battery; CauseStance = Causal Stance (composite score); SciLit = Scientific Literacy (composite score)

Table 6

Bivariate Correlations and Descriptive Statistics for Each Component of Causal Stance

		Scientific Literacy				<i>M (SD)</i>
		3 years	4 years	5 years	6 years	
Causal Stance	<u>3 years</u>					
	Preference	.26*	.17	.00	.17	0.36 (0.29)
	Object	.13	.27*	.27	.22	0.51 (0.34)
	Picture	.33**	.44**	.25*	.29*	0.37 (0.45)
	<u>4 years</u>					
	Preference	.18	.22*	.18	.15	0.47 (0.29)
	Object	-.01	.07	.11	.09	0.69 (0.31)
	<u>5 years</u>					
	Preference	.13	.04	.04	-.06	0.58 (0.26)
	Object	.08	.18	.11	.08	0.71 (0.27)
	Picture	.01	.15	.13	.11	0.82 (0.22)
	<u>6 years</u>					
	Preference	.14	.19	.18	.02	0.50 (0.23)
	Object	.31**	.37**	.08	.19	0.70 (0.20)
	Picture	-.15	-.15	.07	-.15	0.79 (0.20)

Note. Preference = Causal Preference task; Object = Novel Object Inquiry task;
Picture = Novel Picture Inquiry task

** $p < .01$, * $p < .05$

Table 7

Parameter Estimates from Multivariate Regression (with Individual Measures of Causal Stance)

Outcome	Predictor	Unstandardized		Standardized		<i>p</i>	95% CI	
		<i>B</i>	<i>SE</i>	β	<i>t</i>		<i>LL</i>	<i>UL</i>
SciLit (4 years)	Intercept	-0.33	0.52		-0.64	.525	-1.36	0.69
	SciLit (3 years)	0.47	0.08	.47	5.85	< .001	0.31	0.62
	CogSkill (3 years)	0.01	0.01	.19	2.43	.015	0.00	0.02
	Object (3 years)	0.50	0.25	.17	2.02	.044	0.01	0.98
	Picture (3 years)	0.48	0.19	.22	2.50	.013	0.10	0.87
SciLit (5 years)	Intercept	-1.50	0.55		-2.74	.006	-2.57	-0.43
	SciLit (3 years)	0.29	0.09	.34	3.35	< .001	0.12	0.46
	CogSkill (3 years)	0.01	0.01	.18	1.90	.058	0.00	0.02
	Object (3 years)	0.50	0.31	.20	1.63	.104	-0.10	1.10
	Picture (3 years)	0.15	0.22	.08	0.65	.514	-0.29	0.58
SciLit (6 years)	Intercept	-1.93	0.59		-3.25	.001	-3.10	-0.77
	SciLit (3 years)	0.23	0.09	.27	2.68	.007	0.06	0.40
	CogSkill (3 years)	0.02	0.01	.26	2.57	.010	0.00	0.03
	Object (3 years)	0.36	0.29	.14	1.23	.221	-0.22	0.94
	Picture (3 years)	0.22	0.25	.12	0.89	.375	-0.27	0.71

Note. SciLit = Scientific Literacy (composite score); CogSkill = NIH toolbox Early Childhood Cognition Battery; Object = Novel Object Inquiry task; Picture = Novel Picture Inquiry task; CI = confidence interval; *LL* = lower limit, *UL* = upper limit