Executive Functions Predicting Learning Outcomes in Science & English Learning Tasks

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ABSTRACT

The relation of specific executive functions (EF) skills to learning tasks was explored. Middle and high school students (N=78) completed a series of two cognitive assessments of EF skills (DCCS and Flanker), a cognitive training video game, and two learning tasks (a chemistry-based simulation exploration task and an English Language Arts comprehension task). Exploratory and intercorrelation analysis indicated a significant correlation of $p < .01$ of both the English and science learning tasks to learners' executive functions. However, after controlling for pretest scores and age, inhibition is a better predictor than shifting in the chemistry-based simulation exploration task only. Moreover, results confirmed a previous finding for the chemistry-based exploration task. These results provide empirical evidence for the importance of executive functions in academic settings and a better understanding of the types of learning tasks that use executive functions.

INTRODUCTION

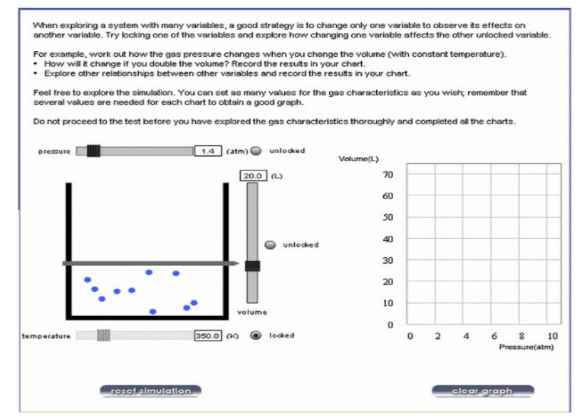
- Executive function (EF), referring to neurocognitive skills involved in self-regulation, is the basis of deliberate, goal-directed behavior. EF has been operationally defined as a construct made up of three lower level base functions: inhibitory control, flexible shifting of one's mental frame, and working memory (Miyake, 2000).
- Developing EF helps us to lead better lives and is found to be more indicative of life success than intelligence quotient (IQ), predicting math and reading achievement, as well as success in career, marriage, and positive mental and physical health.
- A growing body of literature has suggested executive functions to be the underlying processes to early learning, acting as a foundational base that promotes learning.
- Research has shown lower-income children to have worse EF than their higher-income peers; this disparity has been suggested as a likely cause to achievement gaps.
- Children are born with a base-level of EF capacity and the ability to develop them as they grow up.
- Several early-education programs have been designed to train EF and have resulted in favorable academic outcomes.
- The objective of this research is to expand the knowledge of which tasks are predicted by a learners' EF skills.

MATERIALS & METHODS

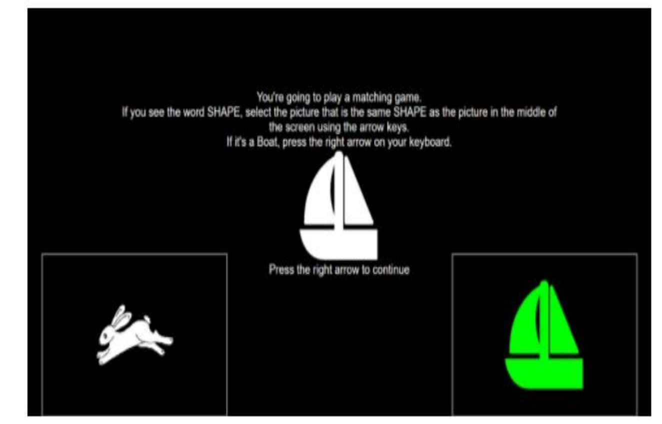
Participants
This study was done in accordance to the institutional IRB guidelines. The participants for this study were recruited from middle and high schools in New York City and New Jersey. Out of 78 students, 37 identified themselves as female, 36 identified as male, and 5 did not respond to the prompt. Participants' ages ranged from 12 to 17 years ($M = 14.32$, $SD = 1.4$ years).

Procedure
A researcher explained the study and obtained informed consent forms from participants before starting. The researcher then remained present to answer any questions. Participants were tested individually at computer workstations in a lab setting. All students completed a battery of tests that were broken up into three blocks of tasks. The first block consisted of completing two cognitive pretests relating to inhibition and shifting EF skills, Flanker task and DCCS task respectively, playing 20 minutes of a cognitive training game, followed by two cognitive post-tests, the same as the pre-tests. The second block consisted of students taking a Gas Laws pretest, interacting with the exploratory version of the *Ideal Gas Laws* simulation, then completing a Gas Laws post-tests. The third block consisted of an excerpt of two passages from an English NYS Regents Examination.

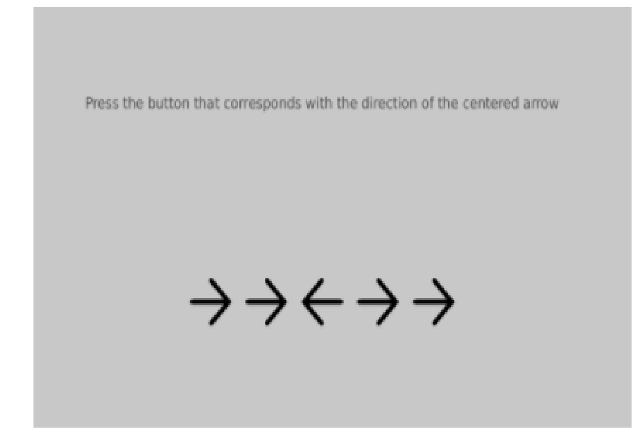
RESULTS



Ideal Gas Laws Simulation



DCCS Task



Flanker Task

Table 1. Intercorrelation of All Measures

		Flanker	GLP	GLC	GLT	RC
DCCS	Pearson Correlation	0.396**	0.415**	0.302**	0.392**	0.474**
	Sig. (2-tailed)	0.001	0.000	0.009	0.001	0.000
	N	73	74	74	74	74
Flanker	Pearson Correlation	1	0.267*	0.288*	0.318**	0.372**
	Sig. (2-tailed)		0.023	0.014	0.006	0.001
	N		73	73	73	73
GLP	Pearson Correlation		1	0.456**	0.105	0.274*
	Sig. (2-tailed)			0.000	0.362	0.015
	N		78	78	78	78
GLC	Pearson Correlation			1	0.419**	0.518**
	Sig. (2-tailed)				0.000	0.000
	N			78	78	78
GLT	Pearson Correlation				1	0.482**
	Sig. (2-tailed)					0.000
	N				78	78

*significance level: $p < 0.05$
**significance level: $p < 0.01$

Table 2. Gas Laws Comprehension Partial Correlations

GLC Correlations					
Control Variables			GLC	Flanker Post	DCCS Post
GLP & Age	GLC	Correlation	1.000	0.233	0.172
		Significance (1-tailed)	.	0.034	0.091
		df	0	60	60
	Flanker Post	Correlation		1.000	0.475
		Significance (1-tailed)			0.000
		df		0	60
	DCCS Post	Correlation			1.000
		Significance (1-tailed)			.
		df			0

Table 3. Gas Law Transfer Partial Correlations

GLT Correlations					
Control Variables			GLT	DCC Post	Flanker Post
GLP & Age	GLT Percent	Correlation	1.000	0.085	0.240
		Significance (1-tailed)	.	0.255	0.030
		df	0	60	60
	DCCS Post	Correlation		1.000	0.475
		Significance (1-tailed)		.	0.000
		df		0	60
	Flanker Post	Correlation			1.000
		Significance (1-tailed)			.
		df			0

Table 4. Reading Comprehension Partial Correlations

RC Partial Correlations					
Control Variables			RC Percent	DCCS Post	Flanker Post
Age	RC Percent	Correlation	1.000	0.290	0.300
		Significance (1-tailed)	.	0.011	0.009
		df	0	61	61
	DCCS Post	Correlation		1.000	0.488
		Significance (1-tailed)		.	0.000
		df		0	61
	Flanker Post	Correlation			1.000
		Significance (1-tailed)			.
		df			0

Gas Law Simulations and Comprehension
A correlation analysis indicates the Gas Law Comprehension post-test scores (GLC) are significantly correlated with both DCCS Post-test scores ($r(74) = .302$, $p < 0.01$), and Flanker Post-test scores ($r(73) = .288$, $p < .05$). A partial correlation, controlling for Gas Law pre-test scores and age (Table 2) indicates that Flanker Post-test performance has a significant relationship with Gas Law post-test scores ($r(60) = .233$, $p < .05$). The partial correlation also indicates that DCCS performance is not significantly correlated with Gas Law Comprehension scores ($r(60) = .172$, $p = .091$). The partial correlation indicates that inhibition (Flanker score) accounts for 5.4% of the variance in GLC scores.

Gas Law Simulations and Transfer
Correlation analysis also indicates the Gas Law Transfer post-test scores (GLT) are significantly correlated with both DCCS Post-test scores ($r(74) = .392$, $p < .001$), and Flanker Post-test scores ($r(73) = .318$, $p < .01$). A partial correlation, controlling for Gas Law pre-test scores and age (Table 3), indicates that Flanker Post-test performance has a significant relationship with GLT scores ($r(60) = .240$, $p < .05$), while DCCS Post-test performance is not significantly correlated with GLT scores ($r(60) = .085$, $p = .255$). The partial correlation indicates that inhibition (Flanker score) accounts for 5.7% of the variance in GLT scores.

Reading Comprehension
Correlation analysis indicates that Reading Comprehension (RC) scores are significantly correlated with both DCCS Post-test scores ($r(74) = .474$, $p < .001$) and Flanker Post-test scores ($r(74) = .372$, $p < .001$). A partial correlation controlling for age (Table 4) indicates significant and small to moderate correlations with DCCS Post-test scores ($r(61) = .29$, $p < .05$) and Flanker Post scores ($r(61) = .30$, $p < .01$). The partial correlation indicates that shifting (DCCS) accounts for 8.4% of the variance in RC while inhibition accounts for 9%.

DISCUSSION

- "All students, regardless of their level of EF, showed better transfer of knowledge after interacting with the exploratory simulation (Homer & Plass, 2014) finding was replicated.
- Students performed better on EF tasks (DCCS and Flanker) after interacting with the exploratory simulation (Table 2 and Table 3).
- In the Gas Laws Exploration simulations, inhibition seems to play a stronger role than shifting in gaining content knowledge (comprehension questions) and in the application of content knowledge (transfer questions).
- Both Flanker (inhibition) and DCCS (shifting) are significantly correlated with transfer knowledge ($p < .05$, Table 3).
- A learners' performance on the ELA task is predicted by the level of their EF skills (Table 4).
- Reading comprehension scores were significantly correlated to DCCS and Flanker with inhibition (Flanker) accounting for 9% and shifting accounting for 8% of the variance in reading comprehension ($p < .05$, Table 4).
- Results suggest that reading comprehension uses the executive functions of inhibition and shifting to relatively similar degrees regardless of age (Table 4).

CONCLUSION

- This research is of theoretical and practical significance.
- On the practical side, these findings provide empirical evidence to support the importance of EF in academic settings, especially in ELA and science, and furthered the understanding of the kinds of learning tasks that require mastery of EF skills.
- On the theoretical side, the study provides insights into the types of learning tasks that tap executive functions.
- Given the value of EF in the positive development of children, these findings have important implications for developing a minimal expense education curriculum to nurture the academic and long-term success of students.
- Further directions include a better experimental design to reduce fatigue and boredom in participants and a longer time setting for training EF game.
- Interesting finds such as if a baseline EF is more important than other measurements of EF in predicting learning task outcomes should be addressed.
- The next step is a more extensive study training EF to lead to academic outcomes.

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