Examining the effects of animated representations on students' understanding of dynamic molecular events

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Overview

The complexity of molecular interactions, operating along **multiple spatial dimensions and temporal scales**, are a challenge for the novice undergraduate student to grasp. Students often approach biological phenomena as a series of discrete events, failing to appreciate the critical patterns and relationships of the whole (Tibell & Rundgren, 2010).

In exploring the ways in which students struggle with some complex dynamic concepts, Chi (2005) suggests that **students fail to comprehend emergent or dynamic events** because they seek causality and group entities according to shared perceptual properties. In two related studies, we examined the relative effectiveness of 3D animation for learning about molecular biology, specifically protein conformation and molecular motion in association with a cell-binding event.

Experiment 1

Increasingly complex versions of the same receptor-ligand binding event were depicted in each of four animated treatments (figure 1). This study examined learning along the **complexity continuum**, and asked whether or not complexity is an appropriate predictor of instructional effectiveness.

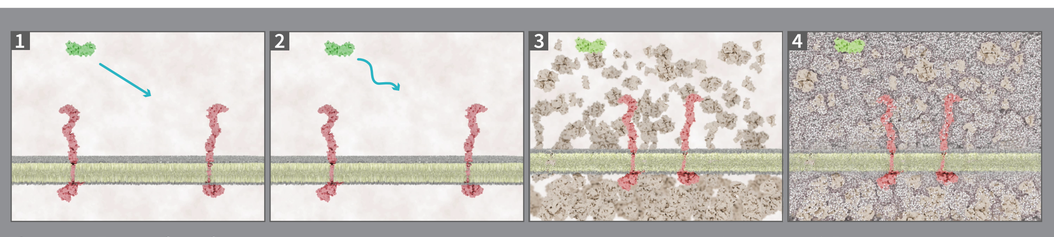

Figure 1. Frames from four animations representing the same receptor-ligand binding event.1) Depicts smooth, directed motion of the ligand towards the receptors; 2) Introduces random, non-directed (Brownian) motion; 3) Introduces molecular crowding; 4) Introduces molecular **water.** Stem cell factor (SCF) ligand and cKit receptor tyrosine kinase were used as a classical example of a ligand-induced receptor dimerization and activation event.

Methods

Students (**N = 131**; Age = 18-24) were recruited from the **undergraduate Biology** program at University of Toronto Mississauga. Participants were randomly assigned to one of four treatments (figure 2). Each of three test instruments (Pre-test, Post-test, and Delayed Post-test) used in this study, included 10 short answer questions. Each test included questions to measure both students' surface level understanding and their deep level understanding.

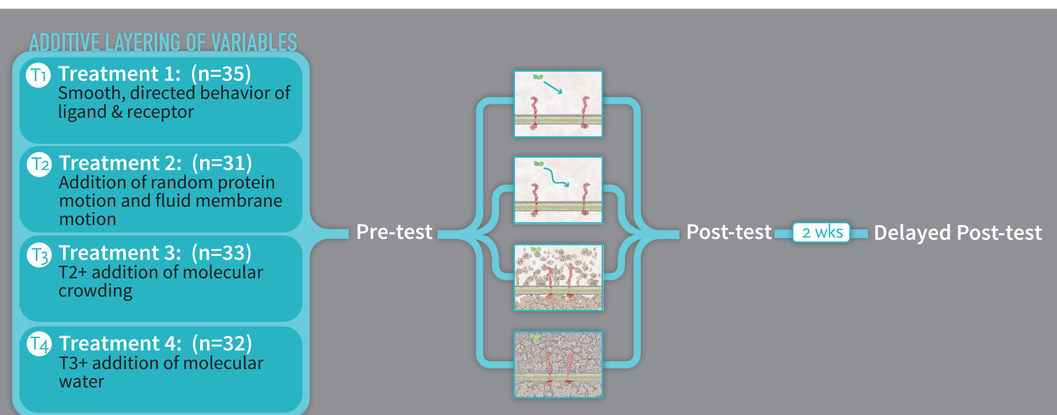

Figure 2. Experimental protocol for assessing the impact additive layering of visual variables upon students' understanding of a receptor-ligand binding event

Findings

A **repeated-measures ANOVA** was conducted to evaluate the **relationship between treatment and knowledge over time**. The results, summarized in the table below, show that test scores varied significantly between pre, post, and delayed post assessment (Wilk's $\Lambda = .665$, $F(2,126) = 31.74$, $p < .001$, multivariate $\eta 2 = .33$). Post Hoc analyses (one-way ANOVA) with a Bonferroni correction were conducted to identify differences between treatment groups at each time point (Table 1 and Figure 3).

Post-test					Delayed Post-test				
Group (I)	Group (J)	Mean (I-J)	Std. Error	Sig.	Group (I)	Group (J)	Mean (I-J)	Std. Error	Sig.
1	2	-.88	.479	.405	1	2	-1.10	.487	.154
	3	-1.66	.471	.004		3	-1.39	.479	.025
	4	-1.53	.475	.010		4	-1.49	.483	.015

Table 1. Post hoc comparisons of Post-test and Delayed Post-test results

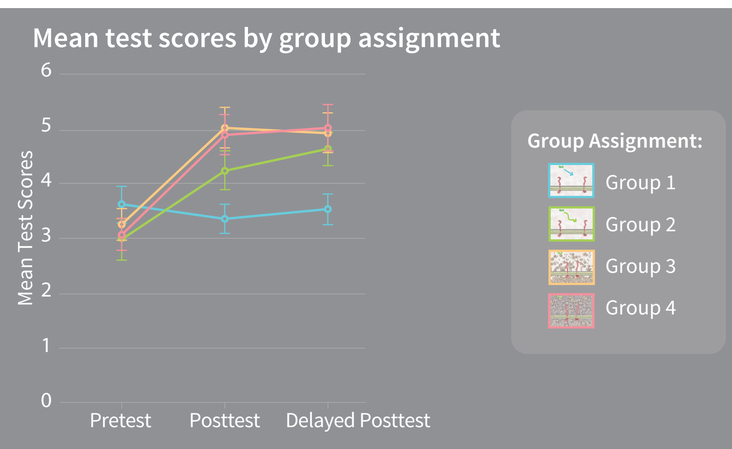

Figure 3. Plot showing group mean test scores at 3 time intervals

Significance

Misconceptions about the molecular realm may be reinforced by the way in which these events are represented. Complex molecular events are often depicted as schematized static illustrations, or as highly simplified animations, that may be interpreted literally by students. Our data show that with **increasing levels of visual complexity students' overall performance improved significantly**, suggesting that under select circumstances schematization or simplification may not be the most appropriate approach to depicting dynamic events.

Experiment 2

The results of this first experiment informed the design of this second experiment, which examined the extent to which perceptually salient features (namely **colour**) contributes to supporting student's understanding of molecular processes as emergent or random (figure 4).

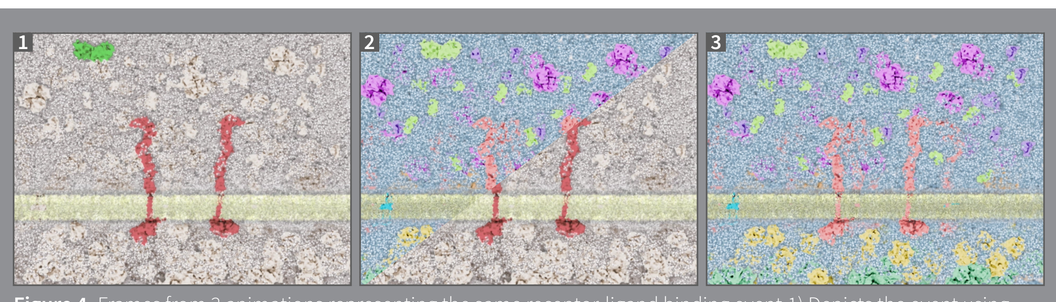

Figure 4. Frames from 3 animations representing the same receptor-ligand binding event.1) Depicts the event using selective colour-coding; 2) Introduces a transition from full colour to selective colour; 3) Represents the event in full colour.

Methods

Students (**N = 61**; Age = 18-24) were again recruited from **undergraduate Biology** at University of Toronto Mississauga. Participants in Experiment 2 were assigned to one of three animated treatments (figure 5) in which **eye movement** data and retrospective **verbal reports** were also recorded (students viewed the animation while their eye movements were recorded and then viewed the animation a second time while verbalizing their thought processes).

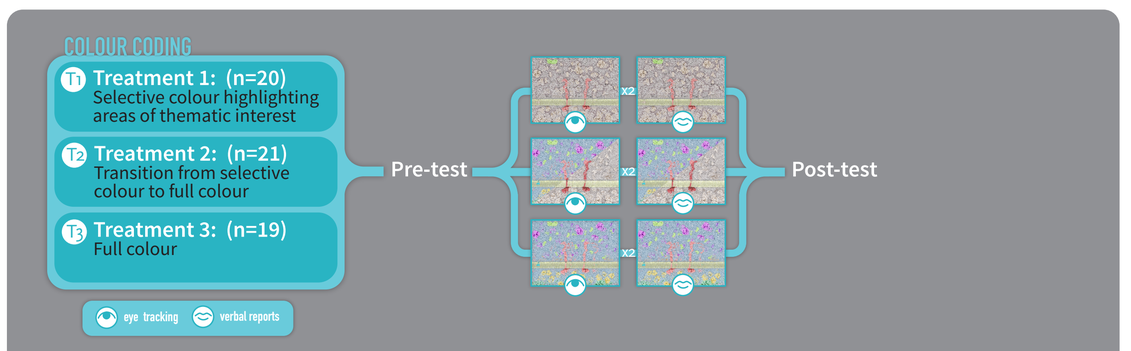

Figure 5. Experimental protocol for assessing the impact of colour coding upon students' understanding of a receptor-ligand binding event

Preliminary Findings

Test scores (Post-test - Pretest) were analysed using **one-way ANOVA with treatment as between-subjects factor**. The results, show that overall test scores varied significantly between pre, post-test assessment (Wilk's $\Lambda = .862$, $F(9.15, 57) = 55.76$, $p < .01$, multivariate $\eta 2 = .14$). However, the **differences between groups was not significant** (Wilk's $\Lambda = .978$, $F(.647, 57) = 3.94$, $p = .53$, multivariate $\eta 2 = .02$). Analysis of eye tracking measures and verbal reports is ongoing. Preliminary findings suggest that there is little difference in how students attend to the visual display regardless of colour treatment. Areas of Interest (figure 6) and fixation data (table 2) are shown here.

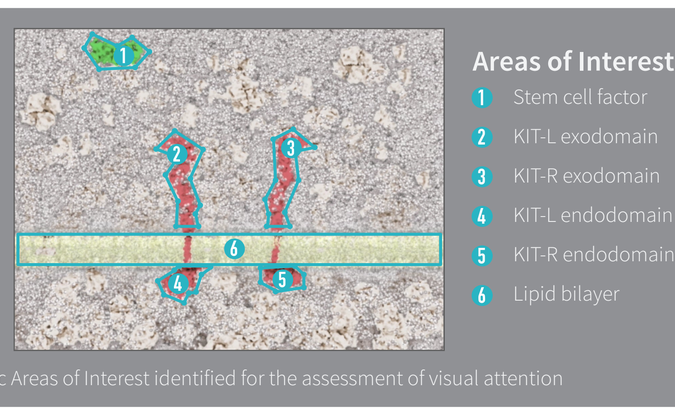

Figure 6. Dynamic Areas of Interest identified for the assessment of visual attention

AOI	Mean Duration			Mean Number		
Stem cell factor	.33	.31	.42	26.8	14.5	10.2
KIT-L exodomain	.30	.29	.29	22.8	18.2	15.6
KIT-R exodomain	.23	.23	.24	14.4	15.5	15.7
KIT-L endodomain	.32	.29	.36	4.5	3.6	4.8
KIT-R endodomain	.28	.29	.32	4.8	3.3	4.5
Lipid bilayer	.31	.32	.34	13.8	17.0	18.9
Non-AOI	.25	.27	.26	51.5	52.1	55.4

Table 2. Mean duration and mean number of fixations in 6 AOIs and 1 non-AOI.

However, our preliminary findings also show that **regardless of the level of visual complexity or presence or absence of selective colour coding students fail to appreciate random motion**. Additional attention must be given to exploring techniques that can satisfactorily balance the random nature of molecular events with narrative explanations of these processes.

References

Chi, M. (2005). Commonsense Conceptions of Emergent Processes: Why Some Misconceptions Are Robust. *Journal of the Learning Sciences*, 14(2), 161–199.

Tibell, L. A. E., & Rundgren, C.-J. (2010). Educational challenges of molecular life science: Characteristics and implications for education and research. *CBE Life Sciences Education*, 9(1), 25–33.

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