Development of a neuroimaging paradigm to dissociate value, weighting, and attention in multi-attribute choice

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// BACKGROUND

1. Decisions are often captured as a **weighted sum** over **multiple attributes** [1]:

$$Summed\ Value = w_1{*}a_1 + w_2{*}a_2 + \ldots + w_n{*}a_n$$

where *a* is how "good" the attribute is, and *w* how "important".
2. Good decisions require **flexibly weighting** attributes according to context or goals.
3. The neurocomputational processes enabling attribute evaluation and flexible weighting remain poorly understood.
4. Unclear how value and attention interact.

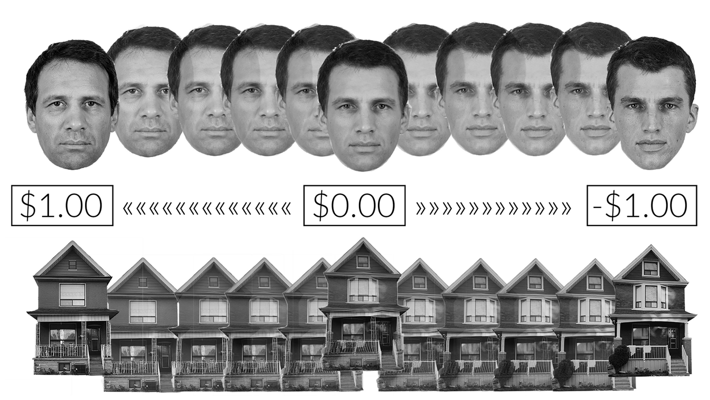
// GOALS

1. Develop fMRI and EEG-compatible paradigm for tracking value and attention during multi-attribute choice.
2. **Investigate** influence of flexible attribute weighting on attention.
3. **Investigate** influence of attention on attribute valuation and weighting.

// METHODS

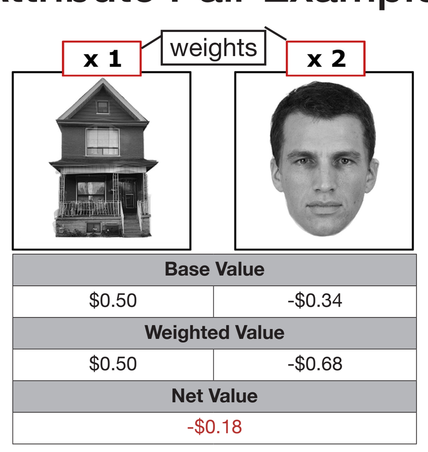
1. Subjects (n=31) learned values from morphed pairs of images of houses and faces.
2. Subjects accepted or rejected a proposed combination of 2 attributes (1 face and 1 house) based on the summed value. Weights were applied to attributes on a trial-by-trial basis to affect importance.

Stimuli

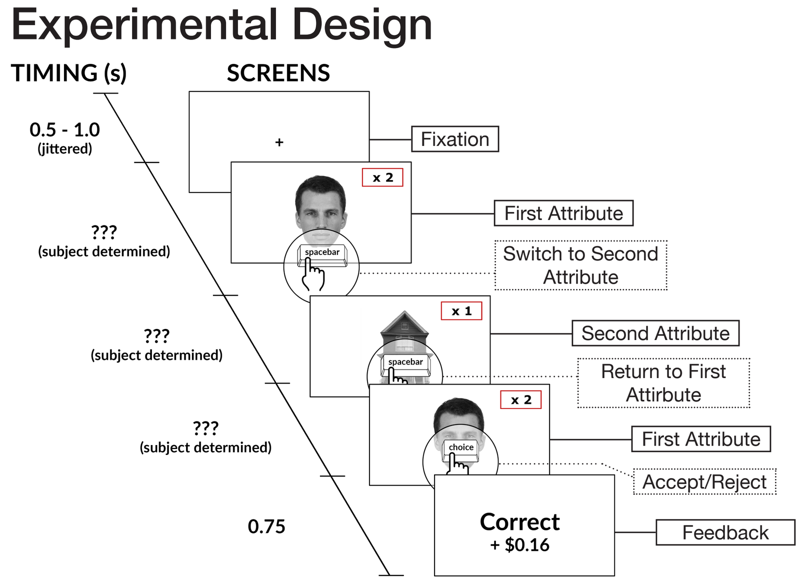


101 morphs, with values from -$1.00 to $1.00, were created. Morphs varied linearly in $0.02 increments.

Attribute Pair Example



Experimental Design



Payment Logic

		CHOICE	
		Accept	Reject
NET VALUE	> 0	Earn $	Lose $
	< 0	Lose $	No Change

Four blocks of 100 trials.

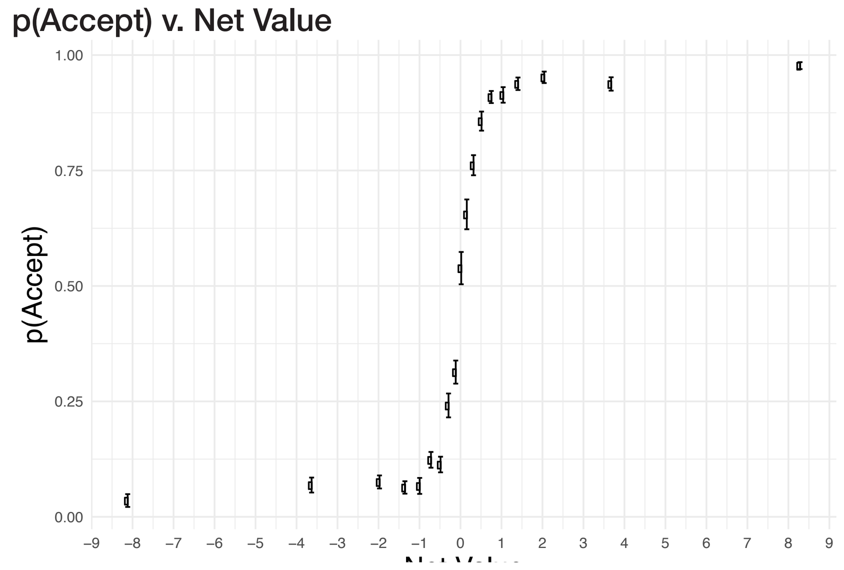
// ANALYSIS

1. Mixed effects regressions to predict choice and accuracy.
2. Hierarchical Bayesian drift diffusion modeling (HDDM [2]) of the parameters:
a (boundary): # of multipliers
t (nondecision): # of fixations
v (drift rate): $\beta_0 + \beta_1{*}Face_{M1} + \beta_2{*}House_{M1} + \beta_3{*}Face_{M2} + \beta_4{*}House_{M2} + \beta_5{*}Face_{M3} + \beta_6{*}House_{M3}$
where β_1-β_6 are the attribute weightings (e.g. $Face_{M2}$ is a Face stimulus with a weight of 2)

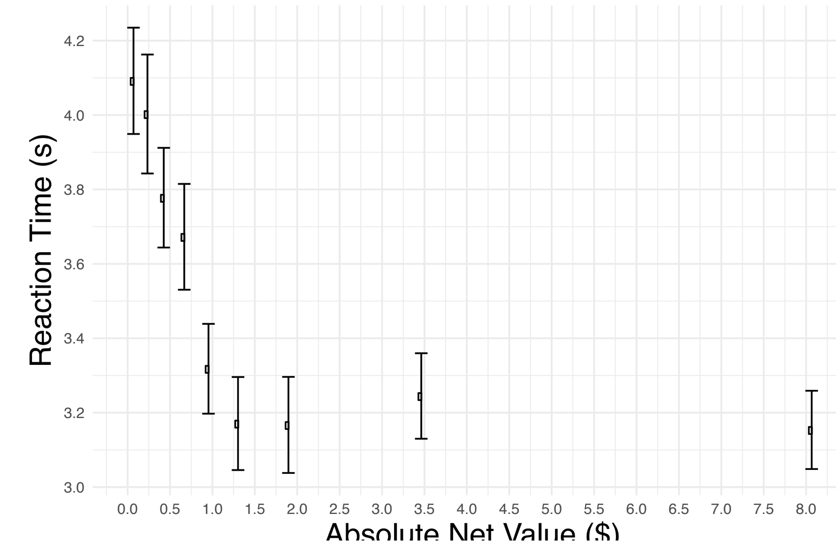
// RESULTS

// Basic Psychometrics

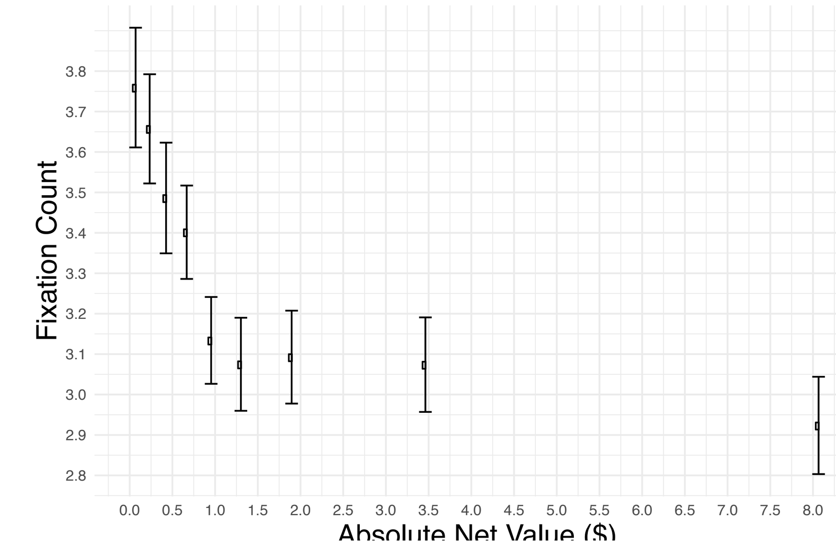
p(Accept) v. Net Value



Reaction Time v. Abs. Net Value



Fixation Count v. Abs. Net Value



// Attribute Re-Weighting

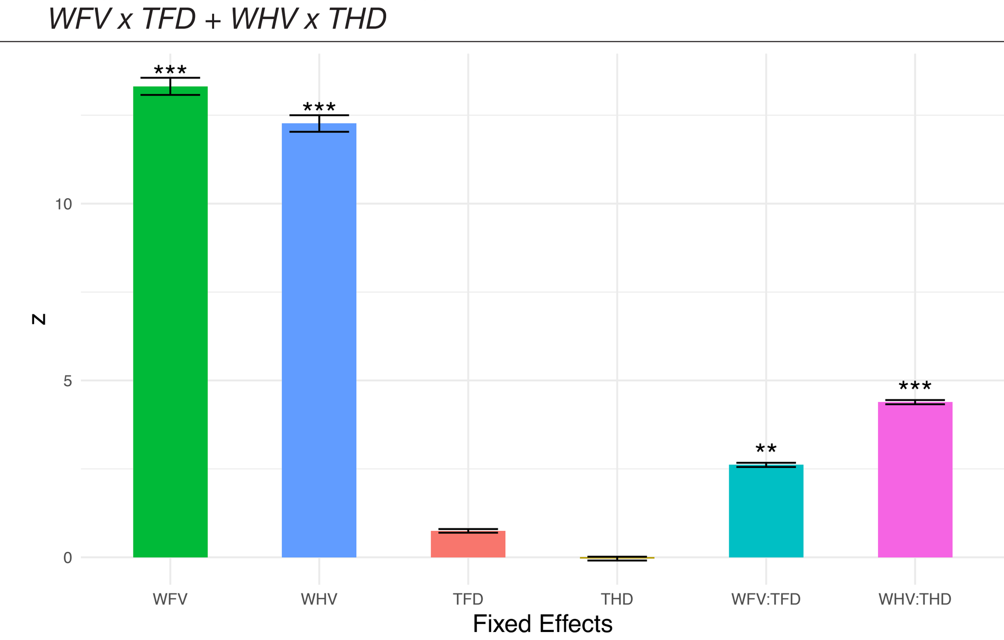
Ideal vs. Measured Multiplier Re-Weighting

1. Subjects effectively re-weighted both attributes at all multiplier levels.
2. Subjects **weighted faces** significantly **more strongly** than houses at all multiplier level.

// Attention, Value and Choice

Mixed Effects Logistic Regression

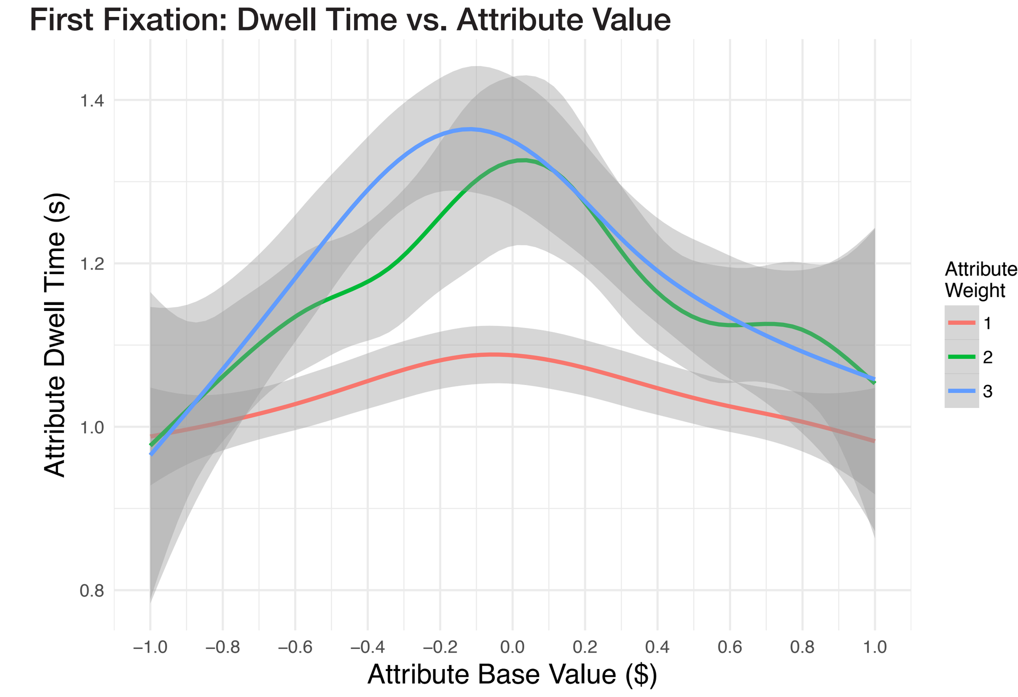
Choice~Weighted Face Value (WFV) + Total Face Dwell Time (TFD) + Weighted House Value (WHV) + Total House Dwell Time (THD) + WFV x TFD + WHV x THD



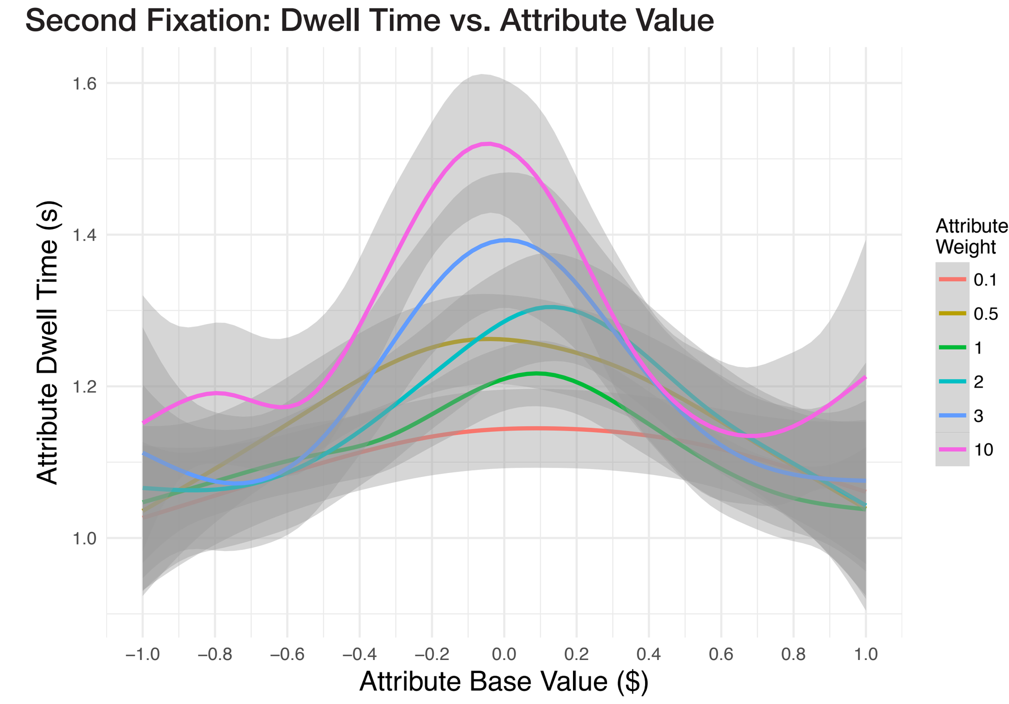
- Attention alone **is not** predictive of choice.
- The **interaction** between attention (total attribute dwell time) and value **is a significant predictor** of subject decisions.
- Results suggest that attention **amplifies** the influence of the target attribute.

// Effects of Attribute Value & Weighting on Attention

First Fixation: Dwell Time vs. Attribute Value



Second Fixation: Dwell Time vs. Attribute Value



Attribute **attention** is **influenced by weighting**, but only for the second fixation (when all decision information is known).

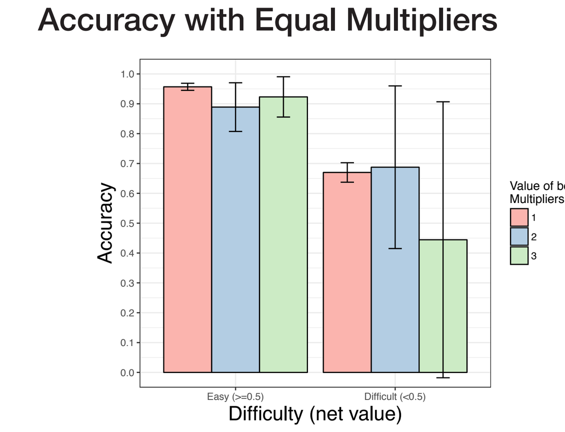
// Weighting, Value and Accuracy

Attention Bias in Difficult Choices

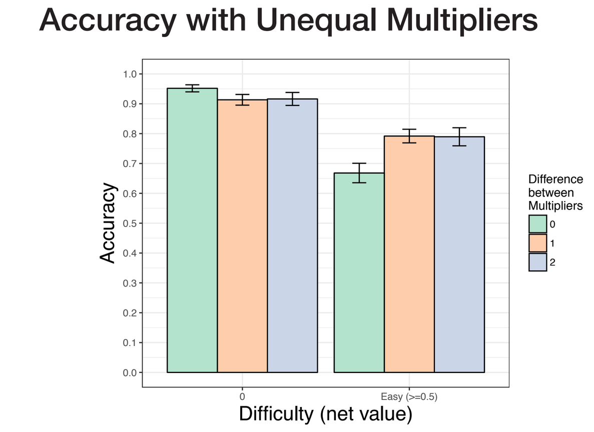
If the number of re-weighted attributes = 0 it means that both attributes had weights of x1.

- For **difficult trials** (-$0.50>Net Value>$0.50), subjects were **more accurate with attribute re-weighting** than without.
- For **easy trials** this relationship reverses.
- This effect does not exist for trials with two equivalent multipliers.

Accuracy with Equal Multipliers



Accuracy with Unequal Multipliers



// DISCUSSION

1. The proposed paradigm can track attention while manipulating value and weighting of attributes.

2. Subjects **are able** to dynamically and **flexibly re-weight** attribute values.

3. More accessible or discernable attributes may tend to be **overweighted**.

4. Attention, as measured by attribute fixation duration, **is not random**. It is affected by value and weighting.

5. Going forward fMRI and EEG will be used to localize the neural correlates of attribute evaluation and weighting.

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// FURTHER INFORMATION

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// REFERENCES

1. Belton, Valerie. (1986). A Comparison of the Analytic Hierarchy Process and a Simple Multi-Attribute Value Function. *European Journal of Operational Research 26* (1): 7–21.
2. Wiecki TV, Sofer I and Frank MJ (2013). HDDM: Hierarchical Bayesian estimation of the Drift-Diffusion Model in Python. *Front. Neuroinform.* 7:14. doi: 10.3389/fninf.2013.00014