Reviewers' comments:

## Editor (Weiwei Zhang):

Our sincere thanks for letting us consider your manuscript at Cognition. Three expert reviewers' comments on your work have now been received. You will see that they are advising against publication of your work. Although the reviewers like the research question, they have some serious concerns on the experimental design (e.g., stimulus durations conceptualized as time pressure and its expected effects on perceptual encoding, Reviewers #1&3), study rationale (e.g., conceptualization of integrality, reviewers 2&3), and statistic power (reviewer #2).  I am in agreement with these concerns and have therefore decided to reject this submission, but invite a major revision. Some of the issues highlighted by the reviewers may be addressable without new data.

I would also like to chime in on the visual persistence issue with the shorter stimulus duration condition (reviewer #3, Dr. Pomerantz). Given the lingering visual persistence after the stimulus offset for up to 500 ms, perceptual encoding would be likely completed. Would any effects reported here a result of some strategical factors?

*That is indeed possible. We assume that what you mean by ‘strategic’ is some sort of decision-making process. However, perception, attention, decision-making and action are presumably not isolated boxes in the brain, so extracting the precise locus of the cause of the effect is extremely difficult. Perhaps more relevant to the current discussion, nowhere in this paper have we said or implied that the effect we are looking at here is entirely perceptual.*

[Re-submission information removed for space.]  
  
Reviewer #1: This paper reports 3 experiments investigating the effect of time pressure on how participants classify integral stimuli. Using a triad task with a set of colored squares varying in chroma and brightness, the authors showed that increasing time pressure increased the use of unidimensional classification. Critically, these results are inconsistent with the idea that integral stimuli are perceived as integrated configurations that require resources for selective attention to a single dimension (Differentiation Theory). Rather, the results support the idea that integral stimuli are initially perceived as separable dimensions which are quickly combined (Combination Theory).  
  
I thought this paper was well-written, tested a clear prediction capable of distinguishing between two competing theories, and the methods and analyses were rigorous and clearly presented. The paper tests a novel, interesting, and counter-intuitive prediction, that a specific type of behavior considered effortful by Differentiation Theory will be easier when participants are given less time to respond. Although by-block classification seemed necessary to detect the effect, the effect was demonstrated in all 3 experiments and Experiment 3 showed that a MDS-informed re-analysis strengthened the effect. The results offer strong support for the authors' conclusions regarding Combination Theory, and have more general implications for perception and cognition (discussed briefly). I enjoyed reading this paper and support its publication in Cognition. I have only minor comments for the authors to consider.

*Thank you, we are glad you enjoyed it.*   
  
Could report proportion in addition to frequency in Table 1 to facilitate comparison between later tables.

*This seems like something easy and simple to change (and thus, we would have done it easily). However, on closer inspection it’s not quite as simple as it seems. First, deciding the ‘denominator’ for a proportion in this table is tricky. The most sensible to us would be say 1/29 (i.e. one participant out of the 29 in that condition used a unidimensional rule). However, that doesn’t really add any information, and may cause confusion because the analysis that Table 1 reports is different to the ones in later tables. Later tables report the proportion of trials that were consistent with a strategy collapsing across participants. Thus, the difference in reporting style (although admittedly inconsistent) may prevent people inadvertently comparing analyses that are different and should be considered with more care. For these reasons, we’ve kept Table 1 the same. We hope you understand.*   
  
Final sentence in first paragraph: should this say "and are considered as primary or privileged stimulus dimensions"?

*Yes, this has be edited – see Line 41, page 3.*   
  
I thought the term "p-hacking" on page 11 was a little strong. I think it's sufficient to describe the analysis in Experiment 1 as post-hoc, especially since the result replicates.

*OK. We have removed the reference to p-hacking and made it clear that it was a post-hoc analysis – see Lines 203-207, page 11.*   
  
If time pressure allows participants to selectively attend to each dimension prior to combination, this should make the integral stimuli more like separable stimuli. The Introduction states that for separable stimuli, there is a strong preference for identity responses, but this didn't occur in the current study. Experiment 3 shows that this might be because the stimuli were not perceived as exactly identical on the dimensions, however this could also be true for studies demonstrating ID responses for separable stimuli. The authors could add some discussion for why ID responses were not more prevalent. For example, is it that UD responding is easier since it doesn't require switching attention between dimensions? If so, why doesn't UD responding also dominate classification of separable stimuli? Or, maybe it does, but the Introduction made it sound like OS was the dominant strategy. The point here is that there still seems to be some difference between separable, and (pre-combination) integral stimuli, which the authors might want to discuss.  
  
*This description and comment slightly misrepresents Combination Theory. Combination Theory does not place selective attention at the beginning of the process. The route is 1. The dimensions are combined, then 2. The dimensions are selectively weighted. This is why we go from unidimensional responding to overall similarity to identity responding as the available time to process information increases. Unidimensional is simplest because the dimensions have not yet been combined, the overall similarity because the dimensions have not yet been selectively weighted, and identity responding is the most effortful as it requires appropriate selective attention to the correct dimension.*

*Moving on to consider the differences between integral and separable stimuli. As we highlight in the first paragraph of this paper, for separable stimuli adults find it easy to attend to one of the stimulus dimensions whilst ignoring the other. In contrast, for integral stimulus dimensions selective attention is more difficult. Thus, Combination Theory proposes that adults when presenting with integral stimuli very quickly and easily combine them and then later take effort to selectively weight the dimensions.*   
  
Reviewer #2:  
In this paper, the authors concluded that integral stimuli are not slowly analyzed, but quickly synthesized. The authors would like to use the Differentiation Theory to explain this phenomenon.

- The Combination Theory assumes that the dimensions of integral stimuli are separable at the first place, however, they are processed holistically, and that's why they are called "integral stimuli". If this is not the intent of what the authors are trying to say in the Introduction section, then the authors should explain this issue more clearly.

*We think you have perhaps misunderstood a little. We compared the predictions of Differentiation Theory and Combination Theory in explaining patterns of categorisation behaviour, and came out in favour of Combination Theory (not Differentiation Theory). Combination Theory argues that cognition begins with the stimulus attributes and that they are combined if time and/or mental resources allow. Combination Theory does not assume that integral stimuli are processed holistically. Please see the first five paragraphs.*

- Please explain more about the "noisy" in the sentence "A strong preference for overall similarity classification in integral stimuli under low time pressure is already well established, and the application of time pressure makes classification data more 'noisy'".

*Happy to clarify – please see line 128, page 7.*

- Please add information about the IRB number.

*Happy to add – please see line, page.*

- In the power analysis, the statistical analysis method should be mentioned.

*This has now been added – please see line 135, page 7.*

- It is hard to understand "There are six different ways in which three stimuli can be placed in three spatial locations and thus each of the eight triads had six different instantiations, resulting in 48 physically different triads per experiment". Please provide the readers with examples in case that the spatial structure of objects formed in the mind of readers is inconsistent with the authors' intent.

*We’ve added an example for a single triad to hopefully make this clearer – please see line 149, page 8.*

- Please be more specific about how the performance of participants was classified into UD, OS, ID, or Bias, and what are the meanings of these four words.

*We’ve added a “Strategy analysis” section to the method to clarify this – please see page 9.*

- Why an experiment with the same stimuli, apparatus, and procedure as Experiment 1 was conducted?

*This experiment was conducted as the key conclusions of the initial experiment were based on post-hoc analyses. This has been explained and clarified in lines 203-205, page 11.*

- The authors mentioned "Crucially, increased time pressure once again increased the prevalence of unidimensional classification of these integral stimuli, BF10= 1047." What are the two groups that are comparing?

*Compared to the other condition without time pressure. Words to this effect have been added – please see line 218, page 11.*

- The sample size of Experiment 3 is limited.

*This comment seems a little misguided as an objective measure of whether the sample size is appropriate or not does not exist for multidimensional scaling experiments (to our knowledge at least). However, past experiments have similar participant numbers. We have now added words to this effect – please see line 238, page 12.*

- Please give some examples of the procedure of Experiment 3.

- The conclusions drawn in this study are based on two dimensional integral stimuli. However, if more dimensions are involved, different conclusions might be found.  
- In the Vigo et al. (2022) paper, a Dual Discrimination Invariance Model was proposed to account for the behavioral results of the integral stimuli. Please refer to it and check if it helpful to explain the results observed in this study and the discussion between Euclidean or Manhattan distance in psychological space.  
- Vigo, R., Doan, C. A., & Zhao, L. (2022, [April 11](http://airmail.calendar/2024-04-11%2012:00:00%20BST)). Classification of Three-Dimensional Integral Stimuli: Accounting for a Replication and Extension of Nosofsky and Palmeri (1996) With a Dual Discrimination Invariance Model. Journal of Experimental Psychology: Learning, Memory, and Cognition. Advance online publication. <http://dx.doi.org/10.1037/xlm0001118>

Reviewer #3: Review of Cognition Ms. COGNIT-D-23-00794  
The rapid synthesis of integral stimuli, by Lori Holt  
Reviewed by James Pomerantz, September 2023  
  
This manuscript reports three experiments testing whether differentiation theory or combination theory better explains result from similarity judgment experiments using squares varying in brightness and saturation, which have been shown to behave as integral dimensions in experiments dating back to the 1960s. The results show support for combination theory, suggesting that integral stimulus dimensions are not initiated fused and then separated through a slow secondary process; rather, it's argued, integral dimensions start out of separate but are then fused through a quick secondary process.  
  
This is an interesting result and one that deserves further attention. I do have some questions and possible reservations about this manuscript, but they may well be addressed in any requested revision.  
  
*Thank you, we are glad you found it interesting.*

First, the primary manipulation in the experiments is stimulus exposure time, either 100ms or 2,000 ms. This is referred to as "time pressure", a term that normally refers to response time, i.e., how quickly Ss try to respond. Many of the tasks used to define stimulus integrality are speeded classification tasks, where Ss are encouraged to respond as quickly as possible, but that was not the case here - there apparently was no deadline for responding. If the combination theory/hypothesis were correct, then selective attention should be easy with all stimuli, since it claims that all dimensions are initially represented separately. Yet Ss cannot (or at least do not) selectively attend to integral dimensions in the speeded classification task.  
  
*We take the point that ‘time pressure’ is a somewhat vague term, perhaps incorrectly used here. We have now changed this throughout the MS to ‘stimulus presentation time’ to reduce the possibility of being misconstrued.*

*The rest of your comment about selective attention slightly misrepresents Combination Theory though. We are not saying that anything can be selectively attended early on. At the beginning dimensions are separate, then combined, then selectively weighted. This is why Combination Theory predicts participants go from unidimensional responding to overall similarity to identity responding as the available time to process information increases. Unidimensional is simplest because the dimensions have not yet been combined, the overall similarity because the dimensions have not yet been selectively weighted, and identity responding is the most effortful as it requires appropriate selective attention to the correct dimension.*

Also, note that while the shorter exposure duration was only 100ms, Ss would have had longer time to respond simply because of visual persistence (ala Sperling). If a mask followed the stimuli, that might change things, but no mask was used (unless the text that followed the stimuli overprinted the stimuli themselves).

*You are entirely right that adding a mask would have been a ‘cleaner’ experiment. However, we do not think that the absence of a mask undermines the conclusions we have drawn from the experiments presented here. It is still the case that the people in the short presentation time conditions have less time available per trial than those in the long presentation conditions (even if the effective duration is longer than the physical duration). Further, the effect is still in the direction predicted by Combination Theory, and in the opposite direction to that predicted by Differentiation Theory. Including a mask might change the effect size, and would probably be desirable in future, but it seems very unlikely that it would change the direction of the effect.*   
  
Relatedly, a very short stimulus presentation may have altered the perception of the colors themselves, given that cones require more energy summed over time to be activated; if so, this would seem to complicate the interpretation of the results, so some control tasks might be needed to determine if the longer and shorter duration color patches appeared the same.

*This is perhaps true: perhaps the stimuli do look subjectively different depending on how long they were presented. However, we can’t think of any sensible control task that would actually enable us to access participants’ subjective qualia to check this in a meaningful way.*

Second, the concept of integrality, as Garner conceived it, was defined by converging operations. That means that the concept was independent of any single system of measurement such as similarity metrics or free classification groupings. A second metric used was what is now called Garner Interference (Pomerantz, 1983 JEP:General; Algom, 2016), which refers to the Orthogonal condition being performed more slowly that the Control condition in Garner's paradigm. A third metric was redundancy gains, which refer to the condition with Correlated dimensions being performed more quickly than the Control condition. There were further measures, but the point is that the notion of dimensional integrality is built on a broad foundation, and any re-evaluation of that notion needs to assess more than just the one metric considered here, namely similarity.  
  
Relatedly, even Garner interference, which is probably the most widely known diagnostic for dimensional integrality, can have multiple explanations. One of them is the one characterized here as differentiation theory holds that these dimensions are initially fused and required slow, secondary processing to separate. Thus, selective attention fails. But there are other outcomes and explanations. For example, consider the classic Garner paradigm with four stimuli resulting from the crossing of two binary dimension, but where the dimensions are the direction of curvature of the left and right elements of parenthesis pairs: ((, (), )(, and )). These stimuli show high levels of Garner Interference (Pomerantz and Garner, 1973), but not because of any failure of selective attention. Rather, Ss do not process the individual parentheses but rather choose to process the pairs of parentheses, because of the emergent features they possess (most obvious is their bilateral symmetry about the vertical axis. So although this manuscript presents a result that might prove to be a challenge for differentiation theory, it will take more work to establish that Garner's concept of integrality got things backwards. As the author also points out, it will be important to extend the research here to include more examples of integral dimensions than the single one tested here (brightness and saturation).

*Our main aim here was to challenge assumptions about Differentiation Theory, not to challenge Garner’s concept of integrality. We totally agree that there is something fundamentally different between integral and separable stimuli, and of course it would be interesting in future research to assess the generality of the effect we have observed here to different sets of stimuli (include stimuli with more than two relevant dimensions) as well as other procedures.*   
  
On p. 9, a bit more needs to be said the four models (unidimensional, overall similarity, identity, and bias). I get their general nature but don't see much in the way of specifics.

*We’ve now added a strategy analysis section to the method of Experiment 1 to address this – please see page 9.*