Is the Colavita Effect Replicable in an Online Study?

BY

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A thesis submitted to the

Department of Psychology

Mount Allison University

in partial fulfillment of the requirements for the

Honours Certificate in Psychology

April 16, 2021

Abstract

Proper functioning in a multimodal environment requires us to be able to bind our senses into a coherent perception of the world. The Colavita effect is an instance of multisensory competition whereby we prioritize visual information over auditory information when they are presented simultaneously. Past research has shown the Colavita effect to be a robust phenomenon through resistance to several experimental manipulations. In recent years, researchers have opted to migrate many psychological studies to online platforms. However, studies of cognitive phenomena present a particular challenge due to their reliance on strict environmental controls. I aimed to examine if the Colavita visual dominance effect would be replicable in an online study. Participants completed a Colavita protocol online and remotely where they were asked to respond to the modality of unimodal (auditory, visual) and bimodal (audiovisual) stimuli. Bayesian analyses revealed that participants did not respond preferentially to the visual component of audiovisual stimuli, and thus did not show evidence for a Colavita effect. Given past success in finding evidence for visual dominance in traditional laboratory settings and robustness in the literature, the absence of the Colavita effect is likely attributable to both the change in environment and variation in environment between participants.

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Acknowledgements

After a chaotically unpredictable five years, I have had the pleasure to encounter peers, faculty, and staff who have shaped my time and trajectory at Mount Allison. I could not possibly thank everyone who helped me get to here, however there are some that I cannot go without mentioning.

Firstly, I would like to thank my supervisor, Dr. Desmarais. My journey in psychology began in your introduction to psychology class in the fall of 2016. At the time, I had no idea where this would take me. Thank you for the opportunities and mentorship you gave me. With you, I was able to show myself that I could be a good researcher, an informed student, and a kind peer. It was in your classes and under your supervision that I learned the most and worked the hardest! Your dedication to all of your students is evident and your passion for the material you teach only serves to make you a phenomenal professor and mentor. Above all else, I am most grateful both for your empathy and for your compassion. The past few years have presented me with unpredictable adversities, and your kindness and empathy each and every time helped me to continue and succeed in my journey here.

To my second reader, Dr. LaPointe, I am grateful to have been here at the same time as you. While you only came to Mount Allison last year, I have been able to take three courses with you and enjoy every one. I will never forget your willingness to be our ill-fated victim in the psychology society’s murder mystery event. It is an illustration of your support for students both in and outside the classroom. Thank you for your guidance and genuine excitement to read every draft I sent your way. I wish you the very best.

Dr. Cormier, while you are not a professor in the department of psychology, your mentorship also guided me here. You believed in me and gave me opportunities to pursue interdisciplinary research (with no computer science knowledge, at that!). Even though I won't be pursuing a career in computer vision, the experience I gained in our work together was invaluable. You never failed to treat me as an equal, showed me kindness, and were incredibly understanding. I could not be more thankful for our work together.

Laura and Sarah E., while I am one year delayed in our respective Mount Allison psychology journeys, I would not be here without you both. The endless stream of laughs in the Crabtree basement, while seemingly so long ago, remain so special to me. We have been lab mates, roommates, givers and receivers of rants, support systems, and friends. Thank you for answering every question I had and reading every draft. As we all continue our student careers into graduate schools, I know we will still support each other from hundreds of kilometers apart.

To Julia and Craig, thank you for endless stream of laughs and support. While you never fail to remind me of my older and ever aging self, I cannot begin to express how thankful I am to have spent this past year alongside you. I could not imagine better people with whom to leave the psychology society. You will both do great things, and I promise to continue providing my unsolicited advice at each and every turn.

Dr. Gould, from the abrupt end to history of psychology this past March to the end of my time at Mount Allison this April, you have proven to be resilient. These past two years have given us much more than we could have ever expected but you have handled it with grace and put students' needs ahead of your own every step of the way. I think I speak on behalf of myself and the rest of the Honours class in saying we are grateful for all you have done for us.

Finally, to the Honours class of 2021, we made it! We couldn’t sit side-by-side in Crabtree, and Zoom seminar just wasn’t the same, but I am proud to have completed this journey alongside you all. Thank you all, and I am excited to see where the future takes us!

Dedication

From reading past theses, I have gathered that dedications are not too often included in a thesis, at least in psychology. The rarity of these occurrences says to me that when they are included, they are special. For this exact reason, I have chosen to dedicate my thesis to my father, Arnold Park.

While he passed a mere week short of the beginning of this leg of my journey, he was there for everything leading up to it. He never failed to support me and was endlessly proud of everything I have, and would, accomplish. Without the compassion, deep love, and unconditional support he had for me, I would not have been able to accomplish this, or anything else for that matter. Although I am filled with a deep sadness that he was not able to see me finish this thesis or my time here, I know he would have read every last page, whether he understood it or not. As this chapter of my life closes and I move on to the next, I become more grateful for him every single day.

Dad, thank you for everything. This is for you. I love you.

Is the Colavita Effect Replicable in an Online Study?

The nature of our world is multimodal, at any given time we experience multiple sensory modalities. We are constantly being exposed to stimuli and our brain has to synthesize this information. Human functioning is contingent on our ability to meaningfully and efficiently form a coherent perception. This is generally known as the cognitive process of multisensory integration. Our perception of the environment is non-reductionist, and our experience relies on the binding of information. Audiovisual integration is the process by which our brain binds information in auditory and visual modalities into a singular percept (Chen & Spence, 2017). When we see and hear something that is creating noise, we do not perceive two individual stimuli, but rather a single perceptual entity. We do not reduce a barking dog to the sound of a bark and the image of a dog. We bind the components together to form a single perceptual entity of a barking dog.

The Colavita effect is an instance of audiovisual integration that demonstrates visual sensory dominance over audition (Colavita, 1974). The Colavita protocol generally involves presenting participants with auditory, visual, and bimodal (audiovisual) stimuli and having them recognize and report the modality of the stimulus presented. In the original methodology, the visual stimulus was a light bulb and the auditory stimulus a 4000Hz sound pressure level (SPL) tone. Participants adjusted the brightness of the light such that it was at an equivalent subjective intensity to the 4000Hz tone at 65dB. Participants were presented with auditory, visual, and bimodal stimuli in a 2:2:1 ratio, respectively and a telegraph key was assigned to each of the auditory and visual stimuli. Participants pressed the key corresponding to the stimulus presented and reported to the experimenter if they believed their answer was correct or not. In the original procedure there was no specific response for bimodal stimuli. Rather, bimodal presentations were framed as “accidental” to participants due to a potential mechanical failure. Colavita (1974), did this as to not reveal the purpose of the bimodal trials. They found that during the simultaneous presentation of auditory and visual stimuli, we often neglect the auditory information in favour of the visual information. On trials where participants failed to correctly identify a bimodal stimulus, their responses reflected a larger number of visual responses than auditory responses. The apparent dominance of visual information during the presentation of a bimodal stimulus has been coined the Colavita visual dominance effect, or the Colavita effect.

The Colavita Effect as a Robust Phenomenon

Since the original study by Colavita (1974), the Colavita effect has continued to be a subject of inquiry. The Colavita effect has persisted though several experimental conditions and manipulations of stimulus type, intensity, and presentation (Colavita, 1974; Desmarais et al., 2021; Huang et al., 2015; Koppen et al, 2008).

Stimulus Type

The type of stimuli presented can affect both the ability to find a Colavita effect and its magnitude. For example, whether the stimuli are abstract, or concrete has been shown to affect the magnitude of the Colavita effect (Desmarais et al., 2021; Koppen et al., 2008). Additionally, concrete stimuli can be either semantically congruent or semantically incongruent. Semantic congruency of stimuli generally describes when the auditory and visual component match, such as a bark and a picture of a dog. Abstract stimuli refer to those that are intangible and are void of both association and sematic context. Previous research has used abstract visual stimuli such as Greek symbols, line drawings, or simply a solid circle (Desmarais et al., 2021; Huang et al., 2015; Sinnett et al., 2007; Yue et al., 2015). Other studies on the Colavita effect have opted to use a light bulb or LED light as opposed to displaying an image on a computer monitor or other display (Colavita, 1974; Colavita, 1982; Koppen & Spence, 2007a; 2007b; Koppen et al., 2009). The majority of studies to have adopted abstract auditory stimuli present a 4000Hz tone; as used in the original Colavita (1974) procedure (Colavita, 1982; Huang et al., 2015; Koppen et al., 2009; Yue et al., 2015). However, Koppen and Spence (2007c), elected to utilize white noise. Within the domain of abstract stimuli, which dominates the literature, the Colavita effect has been a robust finding.

In contrast, concrete stimuli have semantic associations and context, and there is often a material concept for the stimuli. Researchers have previously used concrete visual stimuli such as sounds and images of animals, and simple line drawings of common objects (Desmarais et al., 2021; Koppen et al., 2008; Sinnett et al., 2007). Koppen et al. (2008) investigated how the semantic properties of stimuli affect participants' performance on a Colavita procedure. Images of cats and dogs and their associated sounds were used as the visual and auditory stimuli, respectively. They also tested conditions of congruency and incongruency, when the auditory and visual components match (i.e., the sound of a dog with the image of a dog) or are mismatched (i.e., the sound of a dog with the image of a cat), respectively. When participants failed to properly respond to bimodal stimuli, their errors reflected more visual responses. Koppen et al., describe the magnitude of a Colavita effect to be the percentage of visual only responses minus the percentage of auditory only responses on bimodal trials. While congruency did not modulate the magnitude of the effect, Koppen et al. found a larger effect using the congruent concrete stimuli than what had been previously reported in the literature using abstract stimuli.

Stimulus Intensity

In the original procedure, Colavita (1974) tested participants under conditions of varying stimulus intensity. The first experiment required participants to match the intensity of the visual stimulus, a light bulb, to that of a 4000Hz tone with a fixed intensity of 65dB. The second had participants adjust the intensity of the auditory stimulus such that it was subjectively twice the intensity than that of the fixed visual stimulus. In both instances, Colavita observed a preference toward the visual component of bimodal stimuli. The presence of the Colavita effect during the second experiment with the auditory component subjectively double the intensity of the visual stimulus, reinforces its robustness.

Several subsequent investigations of the Colavita effect have used the auditory parameters of Colavita (1974), a 4000Hz tone presented at an intensity of 65dB (Koppen & Spence, 2007a; 2007b; 2007d). However, some researchers opted to use a similar intensity of 60dB, or a different auditory stimulus presented at 65dB (Koppen & Spence, 2007c; Stekelenburg & Keetels, 2016). Koppen et al. (2009), used a lower intensity of 40.2-41.8dB and were still able to find a Colavita effect. At a higher intensity of 80dB, Colavita (1982), was also successful in demonstrating visual dominance. These findings demonstrate that a Colavita effect can be found using a range of auditory intensity levels.

With respect to visual stimuli, earlier studies used an incandescent lightbulb whereas later studies would employ LEDs. Luminance, a measure of brightness and intensity, for LED light sources have been predominately presented at 1.9cd/m^2 (Koppen & Spence, 2007a; 2007b; 2007c; 2007d). When adjusting a visual stimulus, the participants adjusted such that it subjectively matched the intensity of the auditory stimulus more often than adjusting the auditory stimulus to subjectively match the visual stimulus' intensity (Colavita, 1974; Colavita, 1982). This is likely a result of the ease at which we can control light and measure sound. In a laboratory setting, it is simpler to set the intensity of a visual stimulus and measure the matched sound intensity than the opposite configuration. Further, the measurements for intensity are conventionally only provided for studies using abstract stimuli, most commonly external light sources. Researchers seldom report the luminance of the computer monitor or display used. There are other metrics often provided for monitors (e.g., resolution, refresh rate). An exception to this is Huang et al. (2015), who used a white sphere against a grey background. They reported the sphere's luminance at the aforementioned standard of 1.9cd/m^2. The literature reflects a broad range of stimulus intensities for both the auditory and visual components. In each instance, the Colavita effect was relatively impervious to manipulation of stimulus intensity.

Stimulus Presentation

Variations to how the stimuli are presented has not adversely impacted finding a Colavita effect. Participants continue to show more visual-only responses during bimodal trials even after varying the conditions of stimulus presentation. The original Colavita procedure (1974) presented auditory stimuli through external speakers placed on either side of the monitor being used to display the visual stimuli. Several later procedures have found a Colavita effect employing external speakers to present the auditory stimuli

(Desmarais et al., 2021; Koppen & Spence, 2007a; Koppen et al., 2008; Sinnett et al., 2007). In a follow-up, Colavita (1982), tested if their finding of visual dominance would be resistant to having the auditory stimulus presented directly through headphones as opposed to through speakers. Their objective was to reduce the participant's need to localize the sound, and control for the potential source of interference. The control for spatial localization did not impact the magnitude of the Colavita effect.

Variations in visual presentation have also been successful in finding visual dominance. Koppen and Spence (2007c), sought to examine if visual angle and the relative position of the audio and visual stimuli influenced the Colavita effect. The visual angle of a stimulus refers generally to how a person visually perceives the object. It is often referred to as eccentricity, which is a measurement of distance of the retinal projection from the fovea in units of visual angle. Koppen and Spence used two distinct visual angles, 13 or 26 degrees of eccentricity. They also presented the visual and auditory stimulus on either the same or different sides of the participant. A Colavita effect was found for all conditions of stimulus presentation. However, Koppen and Spence note the magnitude of the Colavita effect was largest when the auditory and visual stimuli were presented from the same spatial position. Moreover, the Colavita effect was not affected by the differences in eccentricity.

The Colavita effect has persisted through variations of stimulus presentation. Presenting auditory stimuli through external speakers or through headphones did not obstruct the dominance of vision over audition on bimodal trials. Analogous to auditory presentation, alterations to visual presentation did not affect visual dominance.

Accounts for the Colavita Effect

In addition to the research on the experimental parameters affecting the Colavita effect, researchers have theorized about the mechanisms underlying visual dominance. Past research has accounted for visual sensory dominance on audiovisual trials using top-down and bottom-up frameworks. *Top-down processes* are those in which our perception is affected by our cognition (Sarter et al., 2001); wherein our previous experience has a tangible impact on how we perceive stimuli. The top-down perspective attributes the Colavita effect to a cognitive phenomenon. How cognition influences our perception is a crucial means for investigating instances of multisensory integration and competition. The converse are *bottom-up processes*, whereby our perception is a product of the sensory input from a stimulus (Sarter et al. 2001). With respect to the Colavita effect, bottom-up frameworks aim to elucidate visual sensory dominance through properties of sensory mechanisms. From this perspective, visual dominance over audition can be accounted for within functional neural and sensory systems.

Top-down Accounts for the Colavita Effect

Top-down accounts generally posit that behaviour is attributable to the influences of cognition. Particular to the Colavita effect, these models ascribe the observation of visual dominance over audition to a bias driven by cognitive processes. A majority of the research on the Colavita effect has taken a top-down perspective, meaning they examine the Colavita effect through a cognitive lens.

Colavita and Weisburg (1979) proposed a top-down account in an inquiry subsequent to Colavita's (1974) original study. The authors used a similar methodology to Colavita (1974), where participants pressed a separate telegraph key for each of the auditory and visual responses. However, the authors asked participants to make their responses to the stimulus offset, or when stimulus presentation ended, as opposed to responding at the onset. Colavita and Weisburg argued that measuring participants' responses to onset and offset are equal sensory measures, however, it is possible that measuring responses to stimulus onset, unlike offset, engages the attentional orienting response and this may lead to quicker motor responses. Further that this orienting may not be equal in responding to onsets and offsets. Thus, if the Colavita effect were a sensory artefact, responses to stimulus offset would lead to a similar or diminished level of visual dominance on bimodal trials. On the contrary, a predicted increase in visual dominance on bimodal trials would support the attentional account.

Colavita and Weisburg (1979) found that participants overwhelmingly responded to the visual stimulus offset on bimodal trials while neglecting to respond to the auditory component and consequently rejected a bottom-up or sensory account. The authors argue that the persistence of visual dominance on offset responses suggests that the Colavita effect does not implicate sensory mechanisms. Attributing the Colavita effect to biases in cognition is a concept that has carried through into more recent investigations.

Modelling the brain as a statistical updating machine has been one view taken by cognitive psychologists. Our brain is fundamentally a probabilistic framework relying on computational principles that makes decisions based on prior information (Pouget et al., 2013). We use probability distributions to compute the probability of an event given the information from our sensory inputs, prior experience, and accrued knowledge to compute the best response to our environment. For example, if we were deciding on the best route to take to a destination, we would use the current state of the environment (e.g., current traffic), and what we have done in the past to inform our decisions (e.g., usual traffic at this time on other days). It could be the case that one route seems like the more efficient option given the information we have immediately available to us, but other knowledge we have from past experiences would lead us to choose another option.

The probabilistic framework has been applied with respect to disentangling the neural mechanisms underlying our ability to integrate multiple sensory inputs to resolve multisensory competition. Accordingly, the probability at which stimuli occur may contribute to the errors observed following bimodal trials. It is possible that the disproportionate proportion of unimodal to bimodal trials is responsible for the Colavita effect, in that our probabilistic model favours unimodal responses as they occur more frequently. A ratio of 40:40:20 auditory to visual to bimodal is used in a bulk of studies on the Colavita effect (Koppen & Spence, 2007d). Unimodal trials compose 80% of all trials and the frequency of each unimodal condition is twice that of the bimodal.

To evaluate the contribution of stimulus probability, Koppen and Spence (2007d), tested participants on a Colavita procedure under varying ratios of trial conditions. Their first experiment increased the ratio, and subsequent probability, of bimodal trials to 60% (20:20:60, auditory to visual to bimodal). Participants completed 6 blocks of 100 trials. When a majority of trials were bimodal, participants responded more quickly to bimodal trials than they did to unimodal trials. Moreover, participants were more accurate during bimodal trials. Despite the overall improved performance in correct responses to bimodal stimuli, Koppen and Spence found a Colavita effect.

To further elucidate stimulus probability, stimulus ratios were adjusted within each participant to vary between blocks. Koppen and Spence (2007d), defined three ratios to be presented to participants: (1) 5A:5V:90B, (2) 25A:25V:50B, and (3) 45A:45V:10B. Each ratio of trials was presented for 5 blocks consisting each of 100 randomized trials, 15 blocks in total. A Colavita effect was observed for all conditions except for the 90% bimodal condition where it was extinguished. While the extinction of the Colavita effect on the high-probability blocks appears to demonstrate that the Colavita effect is a product of stimulus probability, there remains the question of how the brain prioritizes the visual component of bimodal stimuli. Since the auditory and visual proportion remains equal in all of the aforementioned distributions, how can we explain the propensity to make unimodal visual responses on bimodal trials?

Chen and Spence (2017) propose an alternative top-down mechanism for the Colavita effect—the *unity assumption*. The unity assumption is a cognitive phenomenon that describes the predisposition to bind several unimodal stimuli into a single perceptual entity (Chen and Spence, 2017). Observers hold a belief that two individual stimuli ought to be together and will consequently perceive them together; when observed, it is known as the *unity effect*. Grouping stimuli together can serve to fill in perceptual gaps and is largely an adaptive process. Using the unity framework, Chen and Spence explored whether our tendency to group stimuli together is at play in multisensory integration. Is it responsible for the tendency to neglect auditory information and produce the Colavita effect? Chen and Spence's analysis explored 3 phenomena in multisensory integration. Using the architecture for the unity assumption, the authors analyzed the Colavita effect alongside both the McGurk effect and the ventriloquism effect; two other instances of audiovisual integration that are the result of participants resolving multisensory competition.

The McGurk effect describes a phenomenon in speech perception. When the auditory and visual components of a person mouthing a syllable do not match, participants describe hearing a different, third sound. This is the result of participants resolving the competing sensory inputs (Chen & Spence, 2017). The Ventriloquism effect occurs when participants perceive speech as being produced by a person mouthing word. However, the speech is being presented from a different location and participants falsely attribute the speech as coming from the person. In both the McGurk and Ventriloquism effects, altering stimulus presentation did modulate the effects. In the McGurk effect when the sounds and mouth movements occur closer together, and when the context of the speech and mouth movements match both modulate the magnitude of the effect. Similarly, this is true for the spatial and temporal attributes of the auditory and visual components of the Ventriloquism effect. When the auditory and visual stimuli were presented from the same location and closer together in time, participants showed an increased tendency to perceive the sound as coming from the expected source.

In contrast to the McGurk and Ventriloquism effects, the unity assumption did not account for the Colavita effect. On a Colavita task, semantic congruency, whether the auditory and visual stimuli were semantically matched, did affect reaction times. However, it did not impede participants' tendency to neglect auditory components of bimodal stimuli. Chen and Spence (2017) suggest that it is possible that the processes that drive the Colavita effect occur early in the processing of bimodal stimuli and therefore the Colavita effect remains relatively unaffected by semantic components of the unity assumption. Consequently, the mechanism for the Colavita effect may be better resolved through bottom-up accounts.

Bottom-up Accounts for the Colavita Effect

Bottom-up approaches to visual sensory dominance involve investigating the neurophysiological correlates for the Colavita effect. These accounts seek to provide support for the Colavita effect beyond the cognition-centered top-down representations. The intention is to find tangible mechanisms rooted in differential neural activation between unimodal and bimodal trial in the Colavita (1974) procedure.

Huang et al. (2015) aimed to identify the neural underpinnings for the visual sensory dominance in the Colavita effect. Behavioural measures alongside functional magnetic resonance imaging (fMRI) and event-related potentials (ERPs) aided to identify the prepotencies of certain structures to auditory and visual stimuli. Huang et al. (2015), used only two response keys that corresponded to either a visual or auditory stimulus. When bimodal (audiovisual) stimuli were presented, participants were instructed to press both keys. Separating the response keys allowed Huang et al. (2015) to measure the difference at which participants perceived the independent components of the bimodal stimuli. Initial behavioural analyses found a Colavita effect; participants made more visual-only than auditory-only responses to bimodal stimuli. Further analyzing the bimodal trials revealed that on trials where participants did respond to both the auditory and visual components, participants made visual responses before auditory responses.

This apparent prepotency of visual stimuli on bimodal trials was supported by both ERP and fMRI data. When vision dominated audition, the activity in the prefrontal cortex showed an increase both before and after the presentation of bimodal stimuli. Areas in the prefrontal cortex (e.g., ventrolateral prefrontal cortex) have been shown to be included in a network for multisensory integration (Tang et al., 2016). Further, ERPs revealed a connectivity increase between the prefrontal cortex and visual systems during the post-stimulus phase. This is consistent with the fMRI analyses that showed an increase in functional connectivity between these two regions during visual dominance. In sum, when both unimodal keys were pressed on bimodal trials, visual responses were made faster. The inclination to attribute this to preferential sensory processing was supported by both the fMRI and ERP data.

In Colavita procedures, inferences are made about cognition by using a measure contingent on, and perhaps confounded by, motor responses. How information is transferred to the motor system to initiate and perform a response is instrumental in the Colavita procedure and the subsequent measuring of the Colavita effect. Li et al. (2017) acknowledged this relationship and argue that this is the determinant of the competition between multiple stimuli. Specifically, interference to neural preference to vision can be accounted for through motor systems. In a follow-up study, Li et al. (2017), reanalyzed the data of Huang et al. (2015) to explore the implication of visual dominance for motor systems. Li et al. (2017) used lateralized readiness potentials (LRPs) as a metric for neural activation of the motor system. LRPs exploit changes in electrical potential over the motor areas when initiating a motor movement to measure neural activation (Li et al., 2017). Since motor control is contralateral, the potential over the contralateral cortex has a larger change in magnitude than that observed over the ipsilateral cortex when initiating and performing motor movements. LRPs operationalize the observed difference as a mathematical difference by subtracting the ipsilateral motor cortex activation from the contralateral motor cortex activation. Therefore, the difference represents the unique contribution of the contralateral cortex to the observed activation. Li et al. (2017) found that the time between the presentation of an auditory stimulus and the participants' response to it was longer when the auditory stimulus was presented alongside a visual stimulus than when presented alone. By introducing a visual stimulus, there is a distinct neural shift with respect to the perception of auditory stimuli. The competition between auditory and visual information in bimodal conditions is not purely an artifact of cognition; but rather, has objectifiable neurophysiological components.

Huang et al. (2015) and Li et al. (2017) were able to make inferences concerning the neural processes that regulate and drive visual sensory dominance and the Colavita effect. The analysis of behavioural data reflected a Colavita effect (i.e., that participants made more visual-only than auditory-only responses when presented bimodal stimuli) (Huang et al., 2015). Further, neurophysiological data suggested that during visual dominance the motor system prioritizes visual information (Li et al., 2017). Together, Huang et al. and Li et al. present strong evidence for a neurophysiological bottom-up explanation for visual sensory dominance in the Colavita effect.

However, there are findings regarding the Colavita procedure that are not fully encompassed by purely sensory or neural functioning. Recall that for Koppen and Spence (2007d), the Colavita effect was extinguished when participants were exposed to a disproportionately large number of bimodal trials (90% bimodal trials vs. 10% unimodal trials). If the Colavita effect was purely a sensory predisposition, the proportion of trials should not influence the tendency to neglect auditory information in the presence of simultaneous visual information. Dichotomizing the Colavita effect to either a cognitively driven top-down or sensory-driven bottom-up framework does not adequately account for the Colavita effect. Researchers acknowledged this weakness by exploring whether an interaction of the two systems is the mechanism underlying the Colavita effect.

Top-down and Bottom-up Processes Interact to Drive the Colavita Effect

Analyzing and uncovering mechanisms of the Colavita effect from the top-down and bottom-up approaches provides a framework for representing the complex interactions in multisensory integration and competition. The discourse in the literature equally reflects the repeating opposing forces of top-down versus bottom-up. The inability to come to an ultimate conclusion on either side in an equal testament to how we actually perceive audiovisual stimuli. The process by which we integrate audiovisual information may be better explained using an aggregate approach that considers both top-down and bottom-up influences; it is likely the product of both sensory and cognitive processes.

Koppen et al. (2009), propose *signal detection theory* (SDT) as a model for the Colavita effect. SDT uses measures of criterion and sensitivity to stimuli to encompass top-down and bottom-up processes, respectively. The *criterion* represents the propensity of the participant to respond to a stimulus in cases of perceived ambiguity. It can be affected by internal factors and biases; thus, it is a measure of top-down processes. The authors propose that by using SDT they can discretize the possible responses on all trials to form a metric of sensitivity to the auditory, visual, and bimodal stimuli. On any trial, a response can be a: hit, miss, false alarm, or correct rejection. For example, on a visual trial, a hit would be responding that it was a visual stimulus, and a miss would be if the participant pressed any key other than visual-only (responded incorrectly). A correct rejection would be when there is no visual stimulus presented and the participant does not press the visual-only key; and a false alarm would be when the participant responds by pressing the visual-only key in the absence of a visual stimulus. (Koppen et al., 2009). Koppen et al. (2009), define *sensitivity* as the difference between the standardized hits and false alarms (i.e., auditory hits on unimodal trials minus the auditory false alarms on any trial). Therefore, sensitivity is a measure of bottom-up processes.

Comparing the unprocessed error data, analyzing the amount of visual-only to auditory-only errors on bimodal trials, Koppen et al. (2009) found a Colavita effect: participants made more visual-only than auditory-only errors on bimodal trials. With respect to sensitivity, Koppen et al. (2009) did not find any differences between participant's sensitivity to auditory or visual stimuli when presented individually. However, when presented together on bimodal trials, participants' sensitivity to the auditory stimulus decreased. Sensitivity, a measure of bottom-up processes, was modulated by whether the stimuli presented were unimodal or if they were bimodal. The measures of criterion indicated that participants responded differently to the unimodal and bimodal stimuli. The criterion was lower on bimodal trials than on unimodal trials for both stimuli. The changes in both sensitivity and criterion implies that in instances of audiovisual integration, both bottom-up and top-down processes interact to drive perception.

Summary of the Colavita Effect

The Colavita effect is a robust phenomenon of audiovisual integration that represents visual dominance over audition in multisensory competition. It has remained impervious to numerous manipulations and has strong underpinnings in both cognitive and sensory mechanisms. However, all of these manipulations have been concerned with elements within the procedure (e.g., stimulus properties, how participants make responses, etc.). Further, all of the past inquiries into the Colavita effect have collected data from participants in a laboratory setting. These settings are highly controlled and ensure a level of consistency across participants thus, lending to high internal validity. Although, conducting research under these conditions allows for the comparison of findings, perhaps the Colavita effect only occurs in traditional laboratory settings; and other external factors exert undue influence on the nature of audiovisual integration. The next progression to addressing this concern is to move participants out of the lab and into a less consistent and less controlled environment. This change will allow researchers to begin to tease apart if environmental factors contribute to audiovisual integration and the Colavita effect.

Methodology in Online Behavioural Research

Online behavioural research describes the process of hosting cognitive behavioural experiments online. Broadly, online studies are run through similar processes. There is a programming platform that the researcher selects to program their experiment (e.g. JsPsych, PsychoPy, Gorilla). This experiment is then uploaded to an online host (e.g., Pavlovia, PsyToolKit) that the participant will access on an internet browser (e.g., Google Chrome, Safari, Firefox). All of these components are considered software. Hardware are the tangible physical components of the device itself, such as its screen, keyboard, and CPU. The number of factors that comprise an online study introduce the potential for uncontrolled variability that is difficult and often unviable to measure.

Researchers such as Newman et al. (2021) have laid out considerations and concerns for conducting online studies. These include those concerning properties of the sample such as sampling bias and aiming to recruit a wide variety of participants using pre-screening. Newmann and colleagues also present recommendations to ensure data quality such as including “attention checks: during online studies. Active efforts to ensure good data quality are essential to successful online research in any discipline.

Benefits to Conducting Online Cognitive Behavioural Research

With the recent technological advances, many researchers have migrated their studies to online platforms. With the proper vigilance of researchers, hosting studies online offers the researcher several potential benefits. Online studies can reach larger audiences and allow for quicker data collection. Further, the population reached through online studies have been shown to be more representative than in traditional lab studies (Paolacci & Chandler, 2014). As such, the results can be more generalizable. Similarly, access to more participants increases the power of studies. When data are collected online, all raw data is digitized without manual efforts. In addition to reducing resources, it also reduces the potential for data entry errors. This avenue for data collection can serve to reduce other methodological biases as the experimenter and participant do not interact. While cognitive behavioural experiments hosted through online platforms are in a position to utilize these benefits, there are numerous considerations for behavioural studies.

Replicating Lab Results in Remote Settings

To confidently shift traditional lab studies online, a thorough validation process must be conducted. The current approach to validation is replication. If the results from traditional lab studies can be replicated online, then the online study is considered a valid measure of the construct being examined. The replicability of several cognitive tasks on online studies have been investigated (e.g., Stroop task, Posner cueing task, attentional blink) (Crump et al., 2013; Semmelmann & Weigelt, 2017). These tasks rely on strict and consistent controls over stimulus presentation and response recording. Moreover, all of these tasks are well-studied and have consistent and robust findings in the literature.

Reaction Times and Error Rates. Cognitive behavioural studies rely on reaction times (RT) and error rates to make inferences about internal cognitive processes. Both Semmelmann and Weigelt and Crump et al. (2013) analyzed several ubiquitous and well-researched tasks in cognitive psychology that quantified using RT and error rates. Crump et al. (2013) tested whether the in-person laboratory results of four protocols contingent on RT (Stroop task, flanker task, task-switching, Simon task) could be replicated through online testing. Participants completed the study on Amazon's Mechanical Turk (MTurk). MTurk is a service that crowdsources participants to complete tasks that has been coopted by researchers in cognitive science. Participants completed the study remotely on their own devices and chosen web-browser on MTurk. Crump et al. (2013) replicated the patterns of behaviour on each of the tasks.

Semmelman and Weigelt (2017) also tested the replicability of the Stroop and flanker tasks. However, their approach had participants explicitly divided into three conditions: (1) completing the study remotely on the web, (2) completing the study in the lab but on the web, and (3) completing the study in the lab using local software. Online experiments were programmed directly into HTML5/JavaScript and run via Google Chrome web browser, and the in-lab experiment was programmed and run using Matlab. Semmelmann and Weigelt successfully replicated the findings of the lab-based studies in all three of their conditions using RT. Additionally, the authors took an additional measure of analyzing the error rates on these two tasks to see if they also would be consistent with the literature. The error rates on the Stroop and flanker tasks were consistent across the three settings. The replication of Crump et al. (2013) and supplement of the consistent error rates by Semmelmann and Weigelt (2017) provide strong support that online studies are a valid methodology for cognitive experiments.

Stimulus Presentation. In cognitive experiments, researchers rely on the precision with which stimuli are presented to participants. The precision required for these tasks is at the millisecond. As a result, the software used for these studies often market the ability to have timing that is precise below the millisecond, commonly termed "sub-millisecond precision". Online protocols must ensure that stimuli are presented at the proper time and for the proper duration.

In addition to the aforementioned studies, Crump et al. (2013), examined three additional tasks relying on stimulus presentation: the Posner cueing task, the attentional blink, and a masked priming task. Overall, Crump et al. (2013) demonstrate that cognitive experiments requiring precise and controlled stimulus presentation can be reliably conducted online. The Posner cueing task and masked priming task were replicated using MTurk. However, Crump et al. failed to find an attentional blink effect. The authors note their results followed the trends indicative of an attentional blink, but it did not reach the threshold for significance. They note that with greater efforts toward rapid stimulus presentation, it could be possible to find the attentional blink using an online experiment. Semmelmann and Weigelt (2017) equally sought to investigate the attentional blink. They note the attentional blink in particular is a relevant and suitable test due to the necessity of rapid stimulus presentation. Recall the three conditions used by Semmelman and Weigelt; in all cases they were able to find an attentional blink, indicating that the platform they used was able to achieve the precision necessary for the attentional blink.

Experimental Controls in Online Cognitive Research

The attentional blink best illustrates the importance of these controls. While Crump et al. (2013) failed to replicate the attentional blink in their online study using MTurk, Semmelman and Weigelt (2017) found the attentional blink in all of their conditions (local software in lab, online in lab, online remote). Therefore, the environment was not solely responsible for Crump et al.'s inability to replicate the attentional blink. The inconsistency in findings establishes how there are several factors that mediate the validity of online research. Semmelman and Weigelt propose three general considerations to online studies that could impose undue influence on online studies: hardware, software, and environment. As seen in in the aforementioned experiments, these general components are critical. By using their three conditions, Semmelmann and Weigelt, can tease apart the influences of each component and make relevant inferences.

A concern for hardware is the differences in timing among devices; the technical specifications and performance of keyboards, monitors, and speakers all vary. Reimers and Stewart (2015) examined the timing accuracy for recorded response timing over fifteen distinct hardware configurations. Though there were differences in timing across the configurations, Reimers and Stewart note that the variability was very small and should not have undue influence on studies with substantial trials and where very short duration are not essential (i.e., where 25ms is not too large of a timing variation). Importantly, when considering the influence of hardware, the use of within-subject designs eliminates this consideration altogether. Since both Semmelmann and Weigelt (2017) and Crump et al. (2013) were altogether successful in replicating numerous robust cognitive phenomena, hardware likely is not the determining factor in the validity of online studies.

The contribution of the physical environment in which participants complete a study can be inferred by comparing the two online conditions. Having the software (the programming platform, web host, and web browser) remain consistent across all participants, it is possible to infer the difference between the two physical environments: the lab and remote settings. Both Semmelman and Weigelt (2017) and Crump et al. (2013) show that the environment of participants does not exert sufficient influence on them to impede replication on cognitive tasks. While their tasks showed differences in RT and error rates, they observed the expected cognitive phenomena in various environments.

Software is a consideration that the researcher has much more control over. There are limitations imposed by the hardware, but the software optimizes overall performance of the study. Additionally, it is effectively the only source of control for the researcher. While the researcher does not have control over the operating systems and browser used for an online study, they do select the online platform used to host their study. As such, software is a crucial consideration for researcher opting for online studies. Earlier studies used MTurk, as it had access to its own sampling pool. However, MTurk uses a proprietary sampling algorithm and this has raised concerns about sampling bias

(Paolacci & Chandler, 2014). Compounded with the surge of online platforms designed specifically for cognitive experiments, MTurk has fallen out of favour to the benefit of newer platforms.

Bridges et al. (2020) compared the performance of several available psychological software packages both in lab and remotely, and across a variety of web browsers and operating systems. The authors measured the latency of stimulus onset between the visual and auditory stimulus when being presented simultaneously. As expected, their analysis revealed that across all packages analyzed, the variability in the synchrony of the auditory and visual stimuli to be greater when hosted online than when hosted using local lab software. Further, there was a substantial amount of variability between all combination of browsers and software tested. Overall, the two most precise online implementations across the various web browsers and operating systems were Gorilla and PsychoPy/Pavlovia. Gorilla is hosted online and built through their own web-builder. Whereas PsychoPy has a standalone builder and is then hosted automatically through Pavlovia.

Conducting studies online presents abundant sources of error. Despite this, there has collectively been success in replicating cognitive behavioural studies. The persistence of numerous cognitive phenomena in less controlled and more ecologically valid conditions serves to support their robustness and validity.

Survey designs were the first to widely adopt online studies as there were few methodological considerations. Largely, questions and scales are programmed into a software and can be sent to participants. There are cases where online collection is impossible, such as neuroimaging. However, other behavioural questions may be answered, and insights gathered, using peripheral designs. In the cases where it is possible, there are a myriad of potential issues to be taken into account; primarily, reliability and validity. Can we reliably collect data online? Are we certain this is a valid assessment both internally and externally? While these questions were being addressed, efforts to move data collection online has been well-underway for at least the past ten years. In 2013, Crump et al. published their widely cited study on running cognitive studies online through Amazon's Mechanical Turk (MTurk). Since then, many researchers have noted their successes in using online tools. Psychiatry has used smartphone applications to collect behavioural data by redesigning cognitive experiments into games (Gillian & Daw, 2016).

Online Behavioural Research During the COVID-19 Pandemic

As evidenced, conducting cognitive and other behavioural experiments online has been widely shown to be a beneficial endeavour for cognitive psychologists. However, due to the COVID-19 pandemic, online data collection had become substantially more valuable and pursued. Some issues present before the COVID-19 pandemic are exacerbated, such as low recruitment and high attrition (Saberi, 2020). Due to shutdowns and other restrictions, the methodologies available to continue research became limited. Offloading many of the steps in research to online systems allowed many projects to continue, such as the use of webforms for screening, consent, and feedback/debriefing. Consequently, all fields in psychology faced the same issue of online methodology. The questions that can be answered, and the validity of the methods used, come to the forefront. Further, recruitment and incentive allocation (payment, credit granting) can be done entirely remotely and without direct contact, online, or otherwise (e.g., mail). In the case of some cognitive studies, the entirety of the procedure can be migrated online by use of the aforementioned elements in addition to the experimental protocol itself.

There is the concern that the data collected during the pandemic will not be generalizable, given that the effects of a pandemic are more multifaceted than the inability to come into a testing facility. Some concerns have been brought forward by Lourenco and Tasimi (2020), particularly about the demographics of the populations being accessed. Have the effects of the pandemic had undue influence on the samples we are drawing from? For example, some occupations have faced disproportionate rates of unemployment. The expense for internet may no longer be feasible and public access points for internet are no longer open or are very limited. Lourenco and Tasimi stress the importance of extensive demographic data collection when pursuing online studies during COVID-19. In response, Moss et al. (2020) report that the demographic composition of MTurk has remained stable from January 2019 through until May 2020. Further, they address the concern of limited internet access expressed by Lourenco and Tasimi (2020) by noting that a very small proportion of participants on MTurk complete their tasks in public locations, with 98% completing them from home.

Altogether, balancing the restrictions of COVID-19 with promising results before and during the pandemic, there is a basis to warrant conducting behavioural experiments online. Further, there is a sufficient degree of confidence that the data collected will be a valid assessment of the cognitive phenomena, such as the Colavita effect.

Summary and Current Study

The Colavita effect has shown to be a robust cognitive phenomenon. Several studies have successfully found a Colavita effect with variations in the properties of the stimuli. Visual dominance over audition during bimodal stimulus presentation is robust over changes in auditory presentation, visual angle, subjective and absolute intensity, and semantic attributes (Colavita, 1974; Colavita, 1982; Koppen & Spence, 2007c; Koppen & Spence, 2008). Further, cognitive experiments relying on precise stimulus presentation and reaction time recordings have been replicated through online delivery. Taken together, the potential benefits to hosting studies online warrants exploration with respect to the Colavita effect.

The aim of the current study is to determine if, in the absence of strict laboratory control, evidence can be found for a Colavita effect in an online study. Recall, that Koppen et al. (2009) found the strongest Colavita effect when the auditory and visual stimuli were both concrete and semantically congruent. Therefore, I used concrete stimuli and congruent bimodal conditions. I built my experiment using PsychoPy and hosted it online via Pavlovia, as Bridges et al. (2020) found this combination to be a precise platform to host online studies across a variety of hardware and software combinations (Peirce et al., 2019). I had all participants complete a Colavita procedure hosted online. I hypothesized that participants would display a Colavita effect by responding preferentially to visual stimuli over auditory stimuli on bimodal trials.

Method

Participants

A total of 50 participants (36 females, *M* = 19.88 years, *SD* = 2.64) were recruited from introductory psychology classes at Mount Allison University and completed the study remotely. Participants received half of a percent of credit toward their Introduction to Psychology course. All participants reported having normal or corrected-to-normal vision and hearing.

Materials

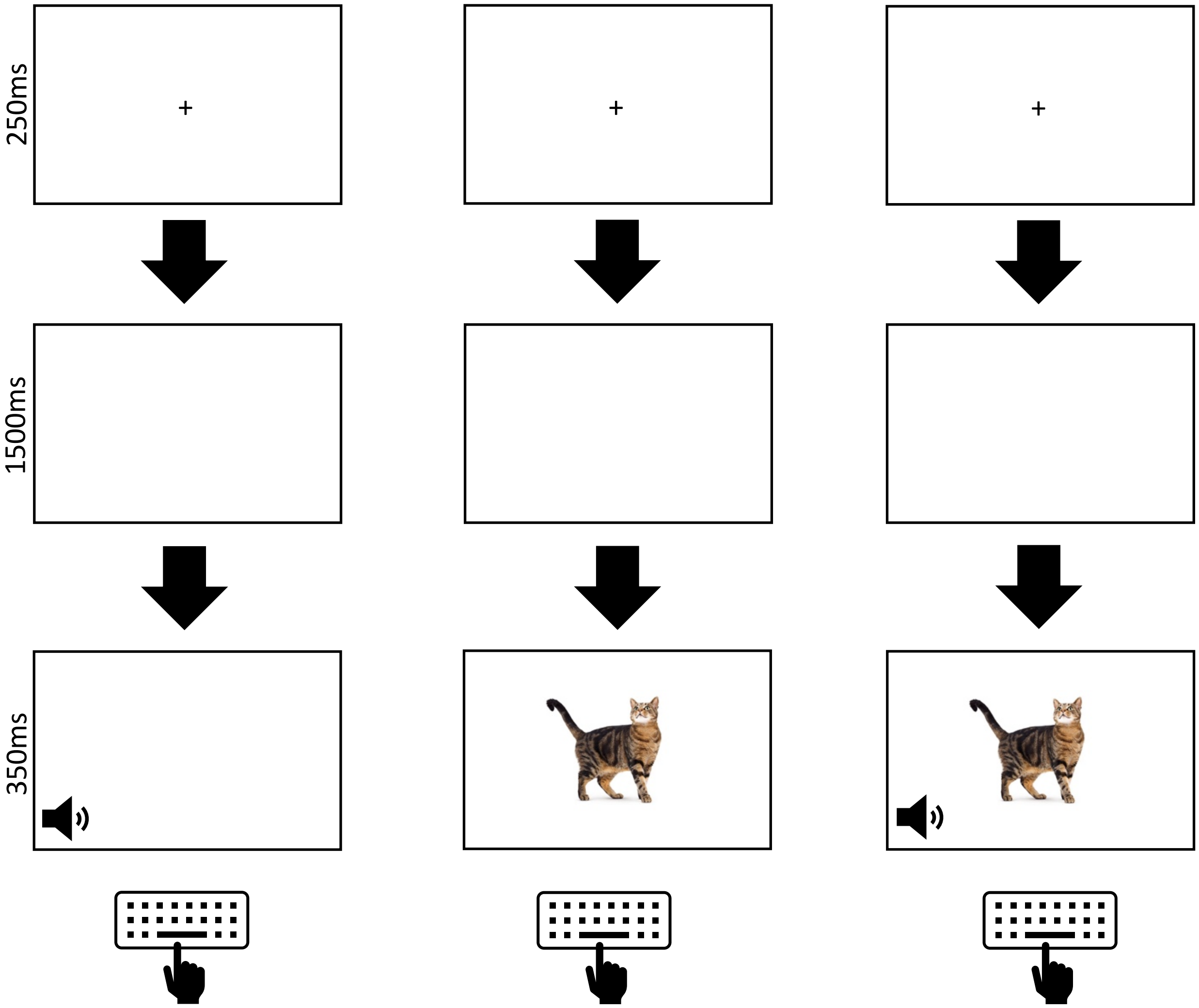
Participants were presented with auditory, visual, and bimodal (audiovisual) stimuli. Visual stimuli consisted of six animals (cat, dog, bird, duck cow, and horse) and auditory stimuli were their congruent sounds. Auditory stimuli presented on remote devices were presented at a volume adjusted by the participant. Visual stimuli presented on remote devices could vary in size depending on the size of the screen but were presented on the middle of the screen. Bimodal stimuli were the presentation of animals and their congruent sounds.

Procedure

First, Participants were presented with a 500Hz tone and asked to adjust the sound level such that the sound could be clearly heard without discomfort. Participants were then presented with auditory, visual, or audiovisual stimuli and asked to report the modality of the stimulus by pressing one of three keys (‘v’, ‘b’, ‘n’). The response associated with each key was counterbalanced across participants. The sequence of events is shown in Figure 1. Participants then completed 120 experimental trials. They were first presented with a fixation cross for 250ms, followed by an interstimulus interval for 1500ms, and then one of the animal stimuli (i.e., a picture, a sound or an audiovisual stimulus). Each of the visual and auditory stimuli were presented 8 times, and each bimodal stimulus was presented 4 times. Participants completed 48 visual trials, 48 auditory trials, and 24 bimodal trials. In total, participation lasted approximately 15 minutes.

Figure 1

Sequence for the Presentation of Events



Note. Each vertical column represents a trial. The left, middle and right columns are the sequence of events seen by participants on auditory trials, visual trials, and audiovisual trials; respectively.

Results

The data from two participants was excluded from analysis as they responded incorrectly to over 87.5% of trials in both of the auditory and visual stimulus trials. The data presented are from 48 participants.

Reaction Times

Mean reaction times for each participant were calculated for each stimulus modality, yielding three mean reaction times per participant (auditory, visual, bimodal). Final mean reaction times were calculated by recursively trimming reaction times at three standard deviations

A one-way Repeated Measures Bayesian ANOVA was conducted in JASP to examine differences in mean reaction times between each of the three trial modalities (JASP Team, 2020). The BF_{10} was 79.84, meaning that the reaction times were 79.84 times more likely to occur under the alternative hypothesis than under the null. This provides very strong evidence for the alternative hypothesis (Wagenmakers et al., 2018). Post-hoc non-directional Bayesian paired-samples t-tests revealed that participants took longer to respond to auditory trials ($M_{\mathrm{aud}} = 1022.83$, $SD = 253.78$) than to visual trials ($M_{\mathrm{vis}} = 926.38$, $SD = 205.07$) ($BF_{10} = 78.90$). Both of the reaction time comparisons between auditory and bimodal ($M_{\mathrm{bim}} = 985.63$, $SD = 233.04$) ($BF_{01} = 1.55$), and visual and bimodal ($BF_{01} = 0.36$) provided anecdotal support for the null hypothesis. This is opposed to my hypothesis that bimodal trials would be longer than both of auditory and visual trials.

Error Rates

Error rates for each trial type were computed by calculating the proportion of incorrect trials to the total trials for the modality investigated. Unimodal error rates were computed for each of auditory and visual trials. Three bimodal error rates were calculated, (1) a total error rate using all incorrect trials over the total number of bimodal trials, (2) an auditory-only bimodal error rate using the number of auditory responses to bimodal trials divided by the total number of bimodal trials, and (3) a visual-only bimodal error rate using the number of visual responses on bimodal trials divided by the total number of bimodal trials.

A one-way repeated measures Bayesian ANOVA was conducted on total bimodal and unimodal error rates (auditory, visual). Contrary to our hypothesis, participants did not show differences in error rates across the modalities tested. BF_{01} was 12.53, suggesting that the data is 12.53 times more likely to have occurred under the null hypothesis than under the alternative hypothesis. This provides strong evidence for the null hypothesis, suggesting that modality did not impact error rates. The cell means are presented in Table 1.

To examine the presence of a Colavita effect, I used a Bayesian paired-samples t-test to compare auditory-only and visual-only responses on bimodal trials. BF_{01} was 5.45 which suggests that data is 5.45 times more likely to have occurred under the null hypothesis than the alternative hypothesis. This provides moderate evidence for the null hypothesis. Contrary to my hypothesis, I did not observe a Colavita effect. See cell means as presented in Table 1.

Table 1

Mean Error Rates for Unimodal and Bimodal Trials

Trial Type	*N*	*M (SD)*	95% Credible Interval
Auditory	48	0.085 (0.191)	[0.030, 0.141]
Visual	48	0.083 (0.203)	[0.024, 0.141]
Bimodal	48	0.096 (0.090)	[0.070, 0.123]
Auditory-only responses	48	0.047 (0.063)	[0.029, 0.065]
Visual-only responses	48	0.049 (0.065)	[0.031, 0.068]

Discussion

I aimed to examine if the Colavita effect could be replicated in an online study. While I expected participants to make slower responses to bimodal trials than to both of the auditory and visual trials, participants did not show reaction time differences across modalities. In analyzing errors, participants made an overall large proportion of errors across all modalities. This was contradictory to my hypothesis as I expected participants to make more errors on bimodal trials than on either of the auditory or visual trials. Further, contrary to my hypothesis I did not find a Colavita effect. Within the bimodal trials, participants did not respond preferentially to the visual component of bimodal stimuli.

The reaction times and error rates observed in my study differed from those found in the literature. I observed reaction times higher than has been previously reported. Recall that Koppen and Spence (2008), also included the sounds and images of cats and dogs as their stimuli and a 2 (auditory):2 (visual):1 (bimodal) trial ratio. I used a larger stimulus set consisting of six animals (cat, dog, bird, duck cow, and horse), and the same trial ratio. Their reaction times for unimodal trials were nearly half of those I observed for unimodal trials and slightly above half for bimodal trials. Desmarais et al. (2021) manipulated attentional load in a series of experiments to disambiguate the role of attention in the Colavita effect. They manipulated attention by asking participants to engage in foot tapping to focus and divide attention on the task and by introducing targets within the stimuli for participants to respond to. Similarly, analyzing the findings of Desmarais et al. (2021), reactions times were generally higher than mine across all of these conditions of varied attention. The reaction times I observed fall between those of Koppen and Spence with similar stimuli, and those of Desmarais et al. using an identical procedure with the exception of attentional manipulations. While this suggests a slowing in reaction times through increased attention load in my findings, further comparison error rates may be more indicative of the mechanism underlying the overall poorer performance I observed.

Of note is the increase in error rates observed for the unimodal trials, which are often very low (Desmarais et al., 2021; Koppen & Spence, 2007a; Koppen & Spence 2008). Using an identical set of stimuli, Desmarais et al. found mean error rates ranging from 3-5% on unimodal trials and across two levels of attentional load through manipulation of target frequency. These are comparatively lower than those I observed at 8.5% and 8.3% for auditory and visual errors, respectively, in my sample. However, Koppen and Spence (2008) reported mean error rates of 8.6% and 11.4% for the auditory and visual trials respectively. While the rates are closer to those I observed, Koppen and Spence found a Colavita effect.

Examining the bimodal error rates, the basis of the Colavita effect, Koppen and

Spence (2008), found a prepotency for the visual component of bimodal stimuli with a visual-only error rate of nearly 20%, compared to an auditory-only error rate below half of 7.1%. In comparison, Desmarais et al. (2021) found overall smaller mean error rates, the highest at 7% for visual-only responses when responding to all targets. A Colavita effect was only observed when participants responded to all stimuli and not when they were tasked with responding to specific targets. Although I did not observe a Colavita effect, my results are most similar to studies that required responding to specific targets. Responding to targets increases the attentional demands of the participant and impeded the bias toward the visual component of bimodal stimuli that is definitive of the Colavita effect.

In sum, my results are more comparable to those with increased attentional demands. I did not purposefully manipulate attention; however, the one methodological distinction was the change in environment from the traditional laboratory to the varying remote environments from which participants completed the study. Consequently, the environment was likely the contributing factor in the inconsistency with previous research on the Colavita effect.

Contribution of the Environment

I did not observe a larger proportion of visual-only to auditory-only responses on bimodal trials that is characteristic of the Colavita effect. By having participants complete my study outside of the lab, the imposition of varied environments is likely a large contributing factor to the overall increase in error rates. While this is presented as one concept, the change in environment presents in and of itself a host of elements, which can be divided into distractions. The methodology I used and methodologies similar have been successful in finding a Colavita effect. Consequently, the lack of this effect is likely attributable to the only distinct methodology shift I used—the change in environment from a controlled laboratory setting to an uncontrolled and varied online setting.

These complex environments present the opportunity for unintentional and potentially detrimental draws on our attention. What properties of environments other than a highly controlled and contained traditional lab are likely to contribute to the extinction of a Colavita effect?

Environments Introduce the Potential for Distraction

To explore how the environment can impact our attention and processing, we revisit bottom-up and top-down accounts for the Colavita effect. In general, our performance is contingent upon our ability to allocate our processing resources. Given this, the external environment is incredibly influential. The elements in the environment range in saliency and the ability to direct our attention away from a task. Recall that bottom-up accounts are stimulus-driven and top-down accounts are goal-driven. Further, it is these two mechanisms and their interaction that contribute to the Colavita effect. We cannot maintain top-down attention to focus on completing a task when our bottom-up attention is being captured by other salient elements of our environment.

The largest shift from the traditional lab to other environments is the imposition of distraction and higher demands for our attention. Desmarais et al. (2021) varied the attentional load imposed on participants in their Colavita task. Participants were asked to respond to the stimuli while simultaneously engaging in a foot tapping pattern. In this condition, Desmarais et al. observed overall slower reaction times and increases in error rates. A foot tapping pattern is a distinct modality from audition or vision. While not interfering directly with processing the stimuli presented, foot tapping still draws on processing resources. Engagement in an unrelated task was illustrated to negatively impact participant performance. Desmarais et al., varied attention by adding targets. Participants were asked to respond to specific targets within the stimuli, when appearing at a frequency of 16.7%, participants did not exhibit a Colavita effect. These low frequency targets increase attentional load of participants, and consequently extinguished visual prepotency on bimodal trials.

Distraction from Natural Environments can Lead to Poorer Performance

When participants complete studies in their remote environments, they are able to disengage from the study. The researcher cannot ensure that they are not using other devices nor other potential distractors, and that their environment is conducive to focus on the experimental task. There exists a plethora of research on device use, primarily cell and smart phones, and our ability to orient our attention to and away from them. Li et al. (2015), suggest that an individual's locus of control is intricately linked to their cellphone use. *Locus of control* can be positioned within a top-down framework, in that is describes how we orient our attention and processing. Broadly, locus of control refers to beliefs concerning our ability to control both the consequences of our actions and our immediate environment. Those with an external locus on control attribute control to the environment, whereas those with an internal locus of control attribute control to themselves as something within them (Li et al., 2015). Li et al. found that, as hypothesized, those with an external locus of control were more susceptible to the negative outcomes of cell phone use; notably, use of their cell phone when not appropriate or optimal. Further, the authors note that this was not related to total cell phone use, rather it is more applicable to immediate events. The inquiry by Li et al. demonstrates how top-down influences, such as locus on control, can affect our ability to ignore or succumb to distractions.

An event such as a notification on a smart phone can be detrimental to participants focus in a two-fold manner. First, the notification is a cue and can draw our bottom-up processing away from the task. Second, a top-down bias, such as an external locus of control, would lend to a higher propensity to orient away from a task and to the notification. The product being impeding the processing required for the Colavita effect by way of both bottom-up and top-down mechanisms. This phenomenon is not exclusive to other devices and distractions such as cell phone notifications but can be generalized to any bias of top-down processing in our environment and the potential interference of other cues.

While examining the impacts of distraction on attentional processing can be done with respect to environmental changes, there has been inquiries into the consequences of involuntary orienting to distractors, a function of bottom-up processing. Escera et al. (2000) describe instances where performance on visual tasks is impeded by novel auditory distractors. Participants were instructed to focus on responding to visual stimuli with an auditory stimulus preceding visual stimulus presentation. When experimenters changed the tone of the stimulus, performance on the task worsened as evidenced by longer participant reaction times.

In a traditional lab there are very few distractions that compete for our bottom-up attention. Further, novel environments promote a distinct top-down framework by removing the biases we have to personal or natural environments. Completing studies in natural environments greatly increases the potential demands for our bottom-up attention. A lab setting aids in directing our processing to the task at hand and reducing opportunities for task-unrelated distractions. In contrast, natural environments promote a less unitarily focused stream of attention on the task. Our way of focusing within our own personal environments is biased toward that environment, and not the novel experimental task at hand. Environments outside of the traditional laboratory are extremely varied between participants. Further, they have the potential to draw on both bottom-up and top-down attention and distract from an experiment. The interference of both attentional mechanisms presents a synergistic detriment to performance.

COVID-19 Pandemic

Data collection for this study occurred during the COVID-19 pandemic. While the effects of a pandemic have the potential to affect data collection and quality beyond the inability to complete testing in a lab, the most direct impact of COVID-19 on this study was the requirement for all participants to complete the study online. The sample in this study was undergraduate students enrolled in an introductory psychology course. Aforementioned sampling biases are not applicable to this study, as the sample used is comparable with respect to demographics to the previous literature where a Colavita effect was found (e.g., Desmarais et al., 2021).

Limitations and Future Directions

One limitation of the current design is that there was only an online condition. As mentioned, the accepted standard for validating online studies for a cognitive phenomenon is through replication (Crump et al., 2013; Semmelman & Weigelt, 2017). For an online study to be a valid measure of an established cognitive phenomenon, it should replicate the findings in the traditional setting. I used similar, and in some cases identical, stimuli to those experiments that have successfully found a Colavita effect (Desmarais et al., 2021; Koppen & Spence, 2007a; Koppen & Spence 2007d, Koppen & Spence, 2008). Given that I was unable to find a Colavita effect online, it could be concluded that my approach was not a valid measure of the Colavita effect. However, to confidently conclude that the Colavita effect cannot be found online, it would be important to use an identical methodology in both the remote and laboratory setting. Additionally, hosting studies online presents a novel array and potential for challenges. To gain better insight on the differences stemming directly from the change in environment and not the online instantiation, there should be a comparison of performance between groups.

Similar to the approach taken by Semmelman and Weigelt (2017), having three groups: (1) remote online, (2) in-lab online, and (3) in-lab local; would allow for better insight into how the environment and other the methodology influence the Colavita effect. Comparing the remote online group (1) to an in-lab online group (2) would aid in disambiguating how the environment alone can affect the patterns of errors participants make and the time to respond. Whereas the in-lab local group (3) would act as an analog to replicate past findings of the Colavita effect. Further, comparing the two online groups to the lab group would provide insight to if the software (e.g., web browser) and hardware (e.g., computer) of the participants could account for a large amount of between participant error.

Future studies aiming to replicate the Colavita effect, or other multisensory phenomena online, may choose to employ attention checks to ensure participants are actively engaged in the tasks (Newman et al., 2021). Past inquiries into the Colavita effect have included several more trials than my experiment. While my study was short and spanned only 120 blocks over 15 minutes, attention may not have been lost as a function of time but rather of environment. For this reason, attention checks may have been able to provide informative insight into the cognitive state of my participants.

Conclusions

I sought to determine if I could find a Colavita effect through an online study with remote participants. I did not find that participants responded preferentially to the visual component of a bimodal audiovisual stimulus. Participants performed worse overall at identifying the stimuli presented to them. Further, these responses took longer than in previous studies. Given the past success in finding a Colavita effect, this generally poorer performance is likely attributable to the change in environment. Highly variable remote environments present the opportunity to capture our attention and distract us from the experiment and result in poorer performance.

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Appendix

Counterbalance Conditions for Key Responses

Counterbalance A: auditory – ‘v’, visual – ‘b’, bimodal – ‘n’

Counterbalance B: auditory – ‘b’, visual – ‘n’, bimodal – ‘v’

Counterbalance C: auditory – ‘n’, visual – ‘v’, bimodal – ‘b’