Background Outline

1. Why is stereopsis important?
   1. Stereopsis is impaired in people with abnormal visual development (Held, Birch, & Gwiazda, 1980; Petrig, Julesz, Kropfl, Baumgartner, & Anliker, 1981; Held, 1991; Birch & Petrig, 1996; Banks, Aslin, & Letson, 1975)
   2. Major factor in everyday visuomotor tasks (Levi, Knill, & Bavelier, 2015)
   3. People with abnormal visual development exhibit deficits in precision grasping (Grant, Melmoth, Morgan, Finlay, 2007; Melmoth, Finlay, Morgan, & Grant, 2009)
   4. Suppression is correlated with poor stereoacuity and visual acuity in the amblyopic eye
   5. Suppression is inherently a binocular problem
   6. By focusing on reducing suppression and improving stereoacuity, other low-level visual functions improve?
2. What is amblyopia and how do we characterize amblyopia?
   1. Neurodevelopmental visual disorder
      1. Typically secondary to strabismus, uncorrected refractive error, and/or deprivation
      2. However, Maurer & McKee (2016) call for a new classification system that takes into consideration the complex interaction between refractive error, spatial visual performance, and eye alignment
   2. Leading cause of visual loss in children (3% of all children)
   3. Classified as:
      1. Reduced visual acuity despite best optical correction (Holmes & Clarke, 2006)
         1. Typically 2-line difference results in unilateral amblyopia classification
   4. Impaired binocular vision
      1. Binocular imbalance (Ding & Levi, 2014)
      2. Poor stereopsis (CITE)
   5. However, people with amblyopia also exhibit:
      1. Poor contrast sensitivity (Hess & Howell, 1977) particularly at higher spatial frequencies
      2. Crowding (Levi & Klein, 1985; Levi, 2008)
      3. Suppression (Tavers, 1938; Birch, 2013)
      4. Deficits in motion perception (Ho & Giaschi, 2007; Simmers et al., 2003)
      5. Contour integration (Levi et al., 2007)
      6. Global motion sensitivity (Kiorpes et al., 2006- primate; Mier et al., 2016)
      7. Visual decision making (Farzin & Norcia, 2011)
      8. Visual attention (Hou et al., 2016; Pham et al., 2018- primate)
3. Treatment techniques for stereo-anomalous/amblyopic observers
   1. Contrast balancing (Hess, Thompson & Baker, 2014; Hess, Mansouri & Thompson, 2010)
   2. Perceptual learning
      1. Improves contrast sensitivity (Li et al., 2009)
      2. Directly train stereopsis (Vedamurthy et al., 2016)
      3. Improves visual acuity (Li et al., 2011)
   3. Dichoptic training (Li et al., 2015; Li et al., 2019; Xi et al., 2014; Vedamurthy et al., 2015)
4. Why use games?
   1. Most training paradigms improve perceptual learning on a specific task (CITE)
   2. Action video game play have been shown to improve sensory, perceptual, and attentional tasks
   3. Differences between gamers and non-gamers can be seen in basic visual functions
      1. contrast sensitivity (Li, Polat et al., 2009)
   4. and higher order visual functions
      1. attention (Green & Bavelier, 2003)
   5. Playing games for a short period of time (10-50 hours) has been shown to enhance vision in normally sighted individuals improving:
      1. Contrast sensitivity (Li et al., 2009)
      2. Crowding
      3. Useful-field of view (Green & Bavelier, 2003)
      4. Attentional-blink (Green & Bavelier, 2003)
      5. Backward-masking (Green & Bavelier, 2003)
   6. Suppression is responsive to video gaming (Foss, 2017)
   7. Playing games has been shown to improve visual function in populations with abnormal visual development
   8. Cue scaffolding
5. Why use VR?
   1. Moving from lab-based to home-based treatments, we need more engaging content and greater game variety (Gao et al., 2018)
   2. Separate images for alignment and contrast balancing
   3. Control disparity content
   4. Scaffolding
   5. Large disparities

Stereopsis plays an important role in everyday visuomotor control and execution (Melmoth & Grant, 2006; Grant, Melmoth, Morgan, & Finlay, 2007; Melmoth et al., 2009). However, abnormal visual experience during the “sensitive period” of development may result in reduced or absent stereopsis (Held, Birch, & Gwiazda, 1980; Petrig, Julesz, Kropfl, Baumgartner, & Anliker, 1981; Held, 1991; Birch & Petrig, 1996; Banks, Aslin, & Letson, 1975).

Amblyopia?

* How do we characterize it?
  + Binocular mechanisms are intact, but functionally suppressed in amblyopia (Thompson, 2019)
  + Categorization of amblyopia based on etiology might be too restrictive. Maurer & McKee (2016) call for a new classification system that incorporates the complex interaction between refractive error, spatial visual performance, and eye alignment
  + Monocular deficits:
    - Impaired visual acuity (Holmes & Clarke, 2006)
    - Contrast sensitivity (Hess & Howell, 1977)
    - Motion perception (Ho & Giaschi, 2007; Simmers et al., 2003)
    - Crowding (Levi & Klein, 1985)
  + Binocular deficits:
    - Suppression (Birch, 2013)
    - Poor stereoacuity

“Amblyopia causes a range of monocular deficits in the affected eye including impaired visual acuity (Holmes & Clarke, 2006), contrast sensitivity (Hess & Howell, 1977), motion perception (Ho & Giaschi, 2007; Simmers et al., 2003), and excessive crowding (Levi & Klein, 1985).”

Why video games?

* Most training paradigms improve learning on a specific task, but the learning does not generalize or transfer.
* Action video game play has been shown to improve sensory, perceptual, and attentional tasks.
* Differences among gamers and non-gamers can be seen in basic visual functions such as contrast sensitivity (CITE),… attention (CITE)…
* Video-game play has been shown to result in an increase in the ability to extract visual information without direct training (Li et al., 2011)

Eye patching alone is not an effective treatment for recovering visual function in adults with amblyopia (Li et al., 2011). Furthermore, there have been a number of studies suggesting that video games may be an effective treatment (CITE). However, there is a debate about whether action video games are more effective than non-action video games (CITE).

Video-game play has been shown to improve uncrowded visual acuity in people with abnormal visual development (Li et al., 2011 AND OTHERS), but not in observers with typical visual development (Green & Bavelier, 2007), possibly due to the smaller room for improvement in people with typical visual development.

Video games have been shown to improve a range of visual functions (list and cite) sometimes, the visual function improved was not trained directly.

Possible mechanisms for broad transfer in video game players

* Probabilistic inference (Green, Pougetm & Bavelier, 2010)

For neural correlates of amblyopia, see Kiorpes & Daw 2018

[From Alyson’s thesis]

Stereopsis has been shown to play an important role in many everyday tasks: allowing better coordination of objects to avoid collision, facilitating through congested environments, and identifying important items within a clustered background, among many others (Stidwill, D. 1998). Roughly 60% of the human visual field overlaps in order to produce stereopsis, postulating that sacrifice of peripheral vision for disparity is beneficial (O’ Conner et al 2017). Thus, adults with compromised stereovision are at a disadvantage, and a common cause of stereo deficits is amblyopia. Amblyopia is just one of the many etiologies that are important to address because having reduced visual acuity in one eye may interfere with detection of binocular disparity cues (Levi et al. 2015). This results in compromised binocular disparity and third degree fusion, or stereopsis (Stidwill, D. 1998). Lifestyle sequelae can occur such as having reduced reading speed, compromised fine motor skills, and limited employment in certain fields (aviation, military, dentistry, and law enforcement among others), showing that consideration towards addressing reduced stereo acuity is beneficial (Kulp MT et al 2014). Though it has traditionally been believed that the brain loses plasticity to visual perceptual treatment after reaching adulthood (Von Noorden 1981), recent studies have proposed otherwise. Numerous studies have shown improvements in visual acuity (e.g., Birnbaum, Koslowe, & Sanet, 1977; Wick, Wingard, Cotter, & Scheiman, 1992) and stereopsis in adults who have compromised functions from amblyopia (Ding & Levi 2011). These studies have shown that there is likely no age cap for treatment, and that improving visual functions is possible.

In recent years, perceptual learning has been utilized as one option for training both visual acuity and stereo acuity. Perceptual learning results in improvements in vision through its repetitive practice for interpreting visual information (Levi & Li 2009). Through perceptual training, stereo-blind participants have demonstrated improvement in their perception of depth after a multitude of trials, and those who had reduced visual acuity (VA) secondary to amblyopia showed improvement in their non-dominant eye (Ding & Levi 2011). This translated to an overall reduced rate of suppression in the non-dominant eye, leading to greater reliance of stereoscopic cues and improved clinical stereopsis as a whole. However, the stimulus normally employed in perceptual learning tends to be dull and boring, which makes compliance and motivation problematic. This limitation plays a moderate role in making large scale, random controlled trials with long term follow ups difficult (Gail et al 2015). With the advent of virtual reality (VR) game play, a combination of perceptual learning in an interactive 3D environment (Vedamurthy, I., et al 2016) may lead to a more effective treatment protocol for adults with visual and stereo deficiencies. It has been confirmed that stereo acuity in particular does improve as measured by Random Dot Stereograms (RDS) (Ding & Levi 2011). However, RDS is not clinically available.

As it has been shown that binocular perceptual training improves not only binocular functions such as stereo acuity but visual acuity in the non-dominant eye as well (Hess et al 2010 and Xi J et al 2014), both visual and stereo acuity performance were examined. Snellen acuities are commonly used to measure VA, and people with reduced visual functions such as those with amblyopia often exhibit a crowding effect in central vision (Levi 2008). In clinical settings, the widely used RandotⓇ stereo acuity tests (Stereo Optical Co, Inc, Chicago, IL) are one of the most common tests for measuring stereopsis and may be the only tool for doing so in many clinical practices. Taking into account both local and global stereopsis, both Randot Circles and random dot diagrams

(Preschool test) will be used.