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# Accelerating Western Balkans University Modernization by Incorporating Virtual Technologies

# VTech@WBUni

## WP2 - Deliverable 2.6.1

# Design of User Experience Guidelines for VR Content

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# 1. Introduction

The scope of the Work package 2.6, are usability aspects of VR solutions and lectures, which will be developed in the scope of this project. The goal of the WP is to provide the best user experience in educational content consumption, which requires consideration of usability and user experience guidelines. The emphasis of this document is therefore user experience guidelines for the development of VR content.

User experience guidelines are necessary as the end users do not have much experience in the domain of VR content usage. One should also consider the fact that different head-mounted devices (HMDs) can be used for such solutions (VR glasses, mobile phones). Furthermore, different interaction modalities (controllers, voice, hand gestures) may be used and consequently, the user experience may differ significantly.

One should also note the difference between VR solutions' specifics due to different usage scenarios, target devices, etc.

The structure of this document is as follows: first, the VR devices and interaction modalities are presented, followed by general VR design guidelines. The latter include guidelines on wireframe setup approaches, prevention of motion sickness, creation of immersive experiences, and natural interaction approaches.

# 2. VR devices and interaction modalities

There are many VR headsets (Head Mounted Displays – HMDs) in the market available today. Despite the same basic functionality, they have different technical capabilities and interaction modalities. These will be shortly discussed in this section.

## 2.1. VR devices and technical properties

The VR devices on the market are different from several technical perspectives. The most important ones are:

- Resolution (per eye)
- Field of view width
- Screen refresh rate

As is presented in Figure 1, most of the HMDs have similar resolutions in the range of HD video. The simpler and mobile HMDs like Oculus Rift and Oculus Go, Samsung GearVR (requires a mobile phone), etc. provide a resolution of 1280 x 1440. In this group is also Sony PlayStation VR device with lower resolution of 960 x 1080. The next group of devices, such as Oculus Quest, HTC VIVE Focus and Pro have somewhat better resolution of 1440 x 1600. In the highest range, more expensive devices provide even higher resolutions, which are in the range of 4K video or half of it (PIMAX 4K: 1920 x 2160, Star VR: 2560 x 1440, Pimax 8K: 3840 x 2160). For the ultimate user experience and a retina quality of the VR scene, one would need even higher resolutions[1], but this is currently very expensive.

The field of view is around 100 degrees for most of the devices, with notable exceptions for PIMAX 8K and StarVR, which have around $200^0$ field of view.

There are more differences in the refresh rates. Most of the HMDs provide a refresh rate between 60 and 90 frames per second, while 120 frames per second are provided by PIMAX 8K and Sony PlayStation VR.

There are also mobile phones, which can be used as VR devices, when inserted in an appropriate headset. The technical parameters obviously depend on the mobile phone used, but the resolution would be in the range of simpler devices (approx. 1280 x 1440) and the refresh rate around 60 frames per second.

All these parameters are important for the user experience. A higher resolution usually means better immersion in the VR world, readability of text, etc. The refresh rate is also an important parameter, as a higher refresh rate may reduce the effect of the so-called VR sickness (described in a later section). This effect is not negligible and may defer users from using VR solutions. The field of view also contributes to general user experience as currently most of the HMDs don't have the field-of view that matches the field of view that the humans have.

[1] *The assumption is that a retina display has 60 pixels per degree, which means 21.600 x 10.800 pixels for the complete $360^0$ scene and taking into account that the user has $120^0$ field of view (7.200 x 3600).*

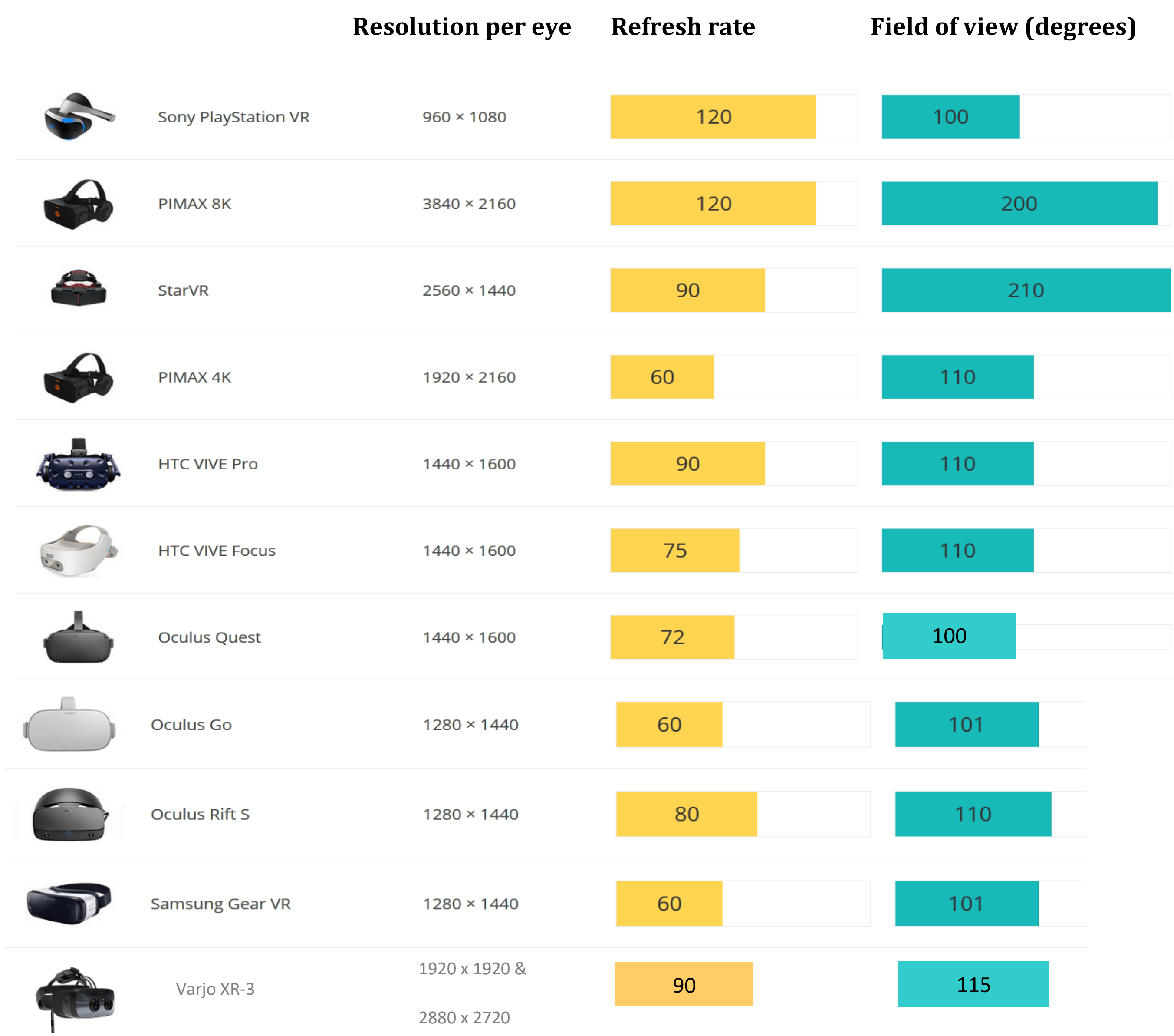


***Figure 1:*** *VR headsets with technical properties (resolution per eye, field of view, refresh rate)*

### 2.2. Interaction modalities

VR services and solutions can be controlled using different interaction modalities. The main modalities include use of controllers, eye gaze, hand gestures, voice control and specific devices, usually targeting narrow domains within VR video games (driving, shooting, etc.):

**Controllers**: there are many different controllers for VR devices, from more complex ones with many buttons (see Figure 2) to simpler ones with one or two buttons. Some HMDs also allow for visual presentation of the controller in the VR word which improves the user experience. For such devices it makes sense to use controller visualisations in the VR scene to show the user, which buttons and controls should be used for different actions.

***Figure 2***. *A VR Oculus Rift controller*

**Hand gestures** control**:** some devices allow for hand gesture control, especially in combination with additional hand tracking hardware such as Leap motion (see Figure 3). Hand gestures are a very natural way of interaction; however, they need to be designed in an appropriate way so the gestures are as intuitive as possible. This usually means that the gestures should resemble natural interaction in real world. Some limitations are of course imposed by the hand gesture recognition devices.

***Figure 3.*** *Hand tracking using Leap motion*

**Eye gaze** control**:** Some VR HMDs, such as Magic Leap can detect the points where the user's eyes are focused. Users can interact with digital content by looking at it (targeting and focusing on digital objects). This interaction modality can be useful in many cases, but it can also be strenuous for the eyes.

**Voice control:** Voice control is also a natural way of interaction. Some VR devices have a built-in support for voice control, but they are currently limited to the environment, settings, etc. However, mobile phones, when used as VR devices, support a wide range of voice commands, because they are already supported by the devices for their standard usage (Apple Siri, Google Assistant).

**Control using other devices:** there are some specific devices that are being used as controllers for specific purposes, such as steering wheels, guns, or other device,s etc. These are usually used in video games but can in some cases also be used for other types of VR content (see Figures 4 and 5).

***Figure 4.*** *Gesture tracking using Mio hand band*


***Figure 5.*** *Specific VR controllers' example*

# 3. General VR design guidelines and design process

General design guidelines for VR will follow the standard user interface design process, which includes the following steps:

- Idea/plan
- Research and user requirements
- Content and information architecture
- Wireframes and visual design
- Prototype and development

Some of these processes are circular as steps 4 and 5 can be repeated after initial user feedback has been gathered and fed back into the development process.

However, the focus of this document is not an extensive description of these steps, but rather giving some tips and hints regarding the user interface design. Therefore, the wireframes and visual design for VR will be described in the following section.

Many of the design guidelines targeting the VR solutions are taken from the general guidelines for the creation of a good user experience. Others are specific to the VR domain, due to the specifics of the end-user device (HMD) and interaction modalities. Below is a list of these guidelines, with a short explanation.

## 3.1. Wireframes setup approach

The full width of the projection represents 360 degrees horizontally and 180 degrees vertically. A typical size of the canvas may differ and is typically in the range of 4K resolutions, which is also a standard resolution for video (3840 x 2160)[2]. For the purpose of this document, we can safely assume the canvas size of 3600 × 1800 pixels. Working with such a big size can be a challenge. In practice, the user will see only a segment of the entire canvas, which is also defined by the resolution of the HMD. Typical HMD resolutions today are in the range of HD, with resolutions of 960 x 1080, 1440 x 1600, 1280 x 1440, etc. Some notable exceptions offer higher resolutions of the display, up to 4K, but these are high-end and more expensive devices.

[2] *With the advancement in technology these resolutions will increase in the future to 12k, 16K or even 24K.*

Therefore, the area of interest typically represents one-ninth or one-tenth of the entire canvas and this should be the target resolution for the design of the user interface (approx.1200 x 600).

Figure 6 presents the sizes of the canvas in 360-degree view and the corresponding size of the user interface view for an approximation of 4K resolution, while Figure 7 presents both for the 24K resolution.

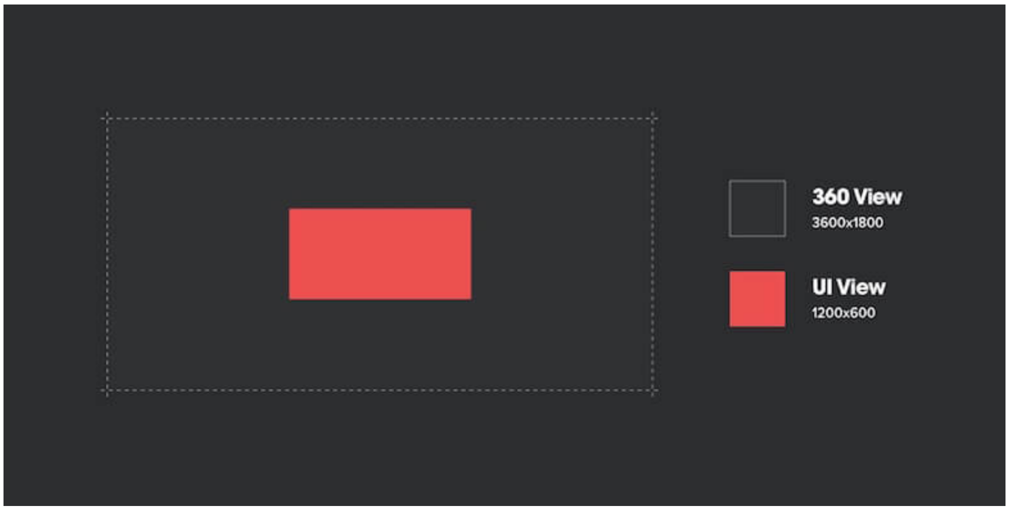


***Figure 6.*** *360 view and UI view for a typical viewing resolution (HD) [1]*


***Figure 7.*** *360 view and UI view for a high-end viewing resolution (4K) [7]*

## 3.2. Prevention of motion sickness

The most common reason for motion sickness in VR is vection — it occurs when eyes tell us we are moving while our vestibular system knows we are perfectly still. It is a consequence of mismatches between physical and visual motion cues. To avoid this effect:

- Never turn off head tracking.
- Move linearly, in short bursts.
- Keep the user in control of their movements.

    - Exceptions are special settings, for example, when the viewer is a passenger in a virtual vehicle. However, even in such cases, allow the user to start the vehicle ride themselves instead of an automatic start.

- Limit the acceleration of the camera and always maintain a steady frame rate.
- If the VR scene is dynamic and requires from the user to move fast in the scenes or the scene includes big objects use a fixed visual reference such as glasses or a hat that the user is wearing in the VR scene.

Other good practice tips include:

- Use higher refresh rates if possible (60fps)
- If the technology allows for it, try to show the users body in the virtual scene (body tracking sensors are required). See Figure 8 for example.
- Reduce changes of brightness: Transitioning between dark scenes and bright scenes can cause discomfort as it takes time for the eyes to adjust to the differences in light. Bright whites and colours should be used in moderation because the increased light is more tiring for the eyes.
- Be cautious with images that convey movement: High spatial images such as stripes and fine textures can enhance the sense of motion and their use should be minimized. Flashing lights should also be avoided.


***Figure 8.*** *User body in the virtual scene using body capture sensors*

### 3.3. Creating immersive experiences

Immersive experiences can improve user experience in VR worlds. There are some good practice guidelines related to creation of immersive experiences:

- **Create a sense of depth and dimensionality:** To ensure this, one can use different ways to create the feeling of 3D space like occlusion, relative sizes of objects, shading, texture gradients motion parallax, etc

- **Provide spatial sound (binaural audio)** to help users feel situated in space. Spatial (directional) audio can increase the sense of realism and provide clues for the user to look around and explore the VR space further.

- **Create an appropriate avatar:** In comfortable situations create an avatar to build immersion. Avatar and the user should be in similar alignment and in sync with user movements. **NOTE:** The users should be disengaged from the avatar in uncomfortable situations, otherwise they may feel pain or discomfort due to body-ownership illusion.

### 3.4. Natural Interactions

User interface elements should be placed a comfortable distance away from the viewer (1.3m to 3 meters). Placing text and images on a slightly curved concave surface feels more natural as the user looks around. Text is currently difficult to read in VR and should be displayed big enough to be legible. Some sources recommended at least 20 px for UI elements and another 2.32 cm height per meter away, but it should be tested to make sure it is big and bold enough for diverse users to read.

***Figure 9.*** *Interaction example using both hands [6]*

**Interactions should be as natural as possible:** If possible, enable interaction using hands, which requires usage of hand motion trackers such as leap motion, MS Kinect or others. In any case use hands or controller for pointing to objects in the VR space and reduce pointing using head tracking. Eye tracking is also an option, but it may be more strenuous than the one using hands or controllers. **Allow for interactions using both hands;** This is a natural interaction mode for humans in the real world (see Figure 9).

**User should be in control:** Provide no or minimum movement without the user's action. This also includes the recommendation that the user should start the VR mode himself/herself.

Even though the virtual world allows for free movement in 360-degree space, there is a limited range of comfortable motion zones. The angles of movement, which are still comfortable are:

- UP:
    - Comfortable: $20^0$
    - Maximum: $60^0$

- DOWN
    - Comfortable: $10^0$
    - Maximum: $40^0$

- LEFT/RIGHT
    - Comfortable: $30^0$
    - Maximum: $55^0$

- SIDE-TO-SIDE
    - Maximum: $15^0$

Figure 10 presents the comfortable and maximum angles of movement.

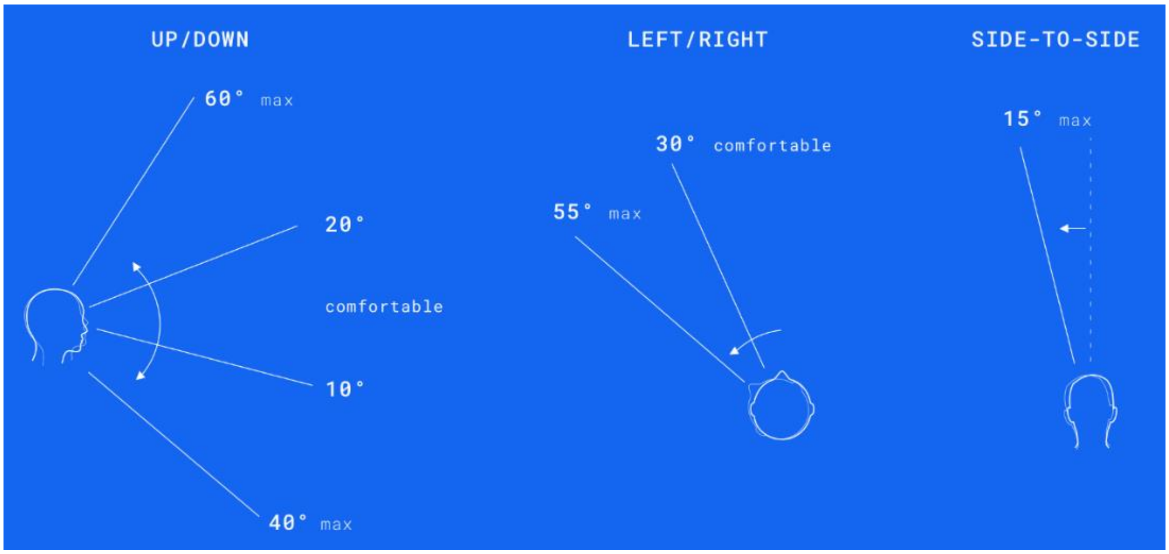


***Figure 10.*** *Comfortable and maximum angles of movement for VR [1]*

Not respecting these motion ranges may cause the "neck-syndrome" as poor posture can create up to 30 kg of pressure on user's spine. This can lead to permanent nerve damage in the spine and neck.

Similarly, looking at the comfort zones in the horizontal plane, we can safely assume that the comfortable content zone (the area where interaction with content items is still comfortable) is:

- Not closer than 0.5 m from the user's standpoint
- $70^0$ to the left and right
- Up to $105^0$ left and right from the viewing axis is the so-called peripheral zone, where items might be noticed, but the interaction with them is not comfortable. The rest is called the curiosity zone, which is the area where the user will not notice any objects/content and needs to change the viewing direction to explore it.

The comfort zones in the horizontal plane are presented in Figure 11.

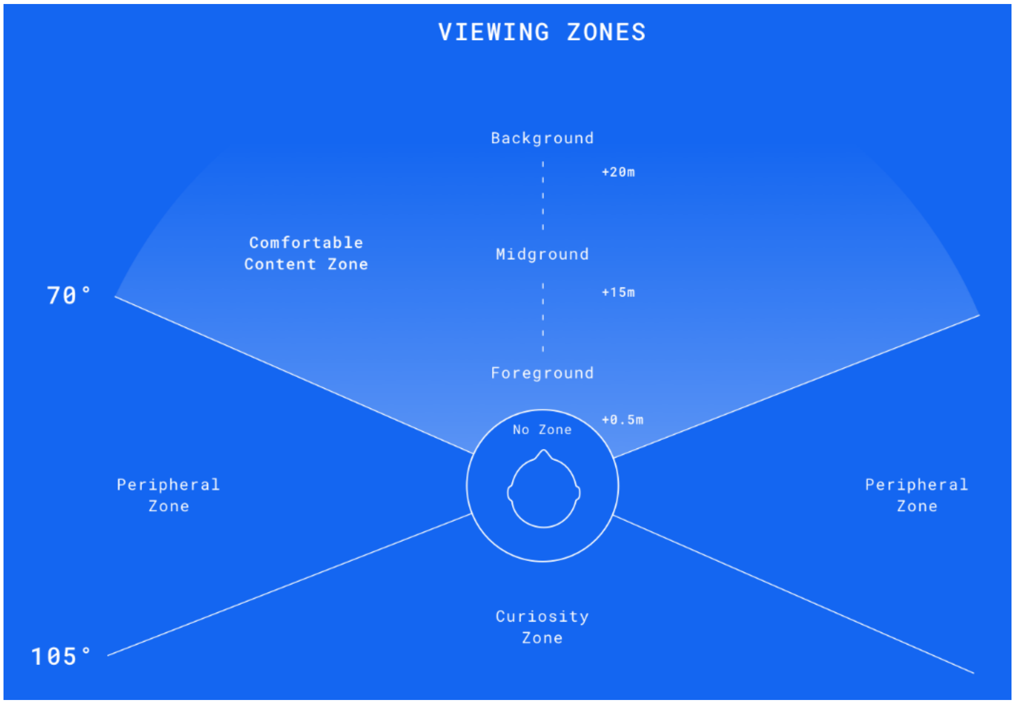


***Figure 11.*** *Comfortable viewing zones [1]*

**Make interactive objects reachable, distinctive, and visible:** the users expect that objects in the VR scene are interactive. Therefore, mark the interactive objects in a specific way or avoid using interactive objects from the real world (example: do not draw door handles if they cannot be used or outstanding buttons on devices in reach if they cannot be activated). The most frequent gestures and interactions should be easy on the hands and body, so users don't get fatigued or injured. Objects that will be used the most should be easy to reach, with suggestions ranging between 0.75–3.5 meters away to 0.50–20 meters away.

Controls should be easy to learn and remember as users have limited memory and will not be able to directly see the controllers while in VR. Especially for users who are new to VR, the number of buttons and gestures needed to interact should be minimized. A good rule of thumb is people can generally only remember 7 chunks of information plus or minus.

One can also try to help make users precise selections. These approaches to interaction design include:

- Accept input for the UI only from a single element such as the index finger, laser pointer, ray
- Display a reticle when the user is doing fine targeting (especially for interaction without controllers – ex. eye gaze)

In order to improve user experience, one should try to build on existing knowledge of the natural 3D world. An example would be inclusion of gestures that simulate grabbing things (items) from a backpack or a holster or using natural colours, shapes and materials to provide interaction with things in an expected way.

Use of standard gestalt and design principles is also recommended, such as proximity, similarity, and hierarchy can all help users make the correct selection quickly. Items should be scaled appropriately and well-spaced to ensure users can hit the correct target, without accidentally triggering targets nearby (see Figure 12).

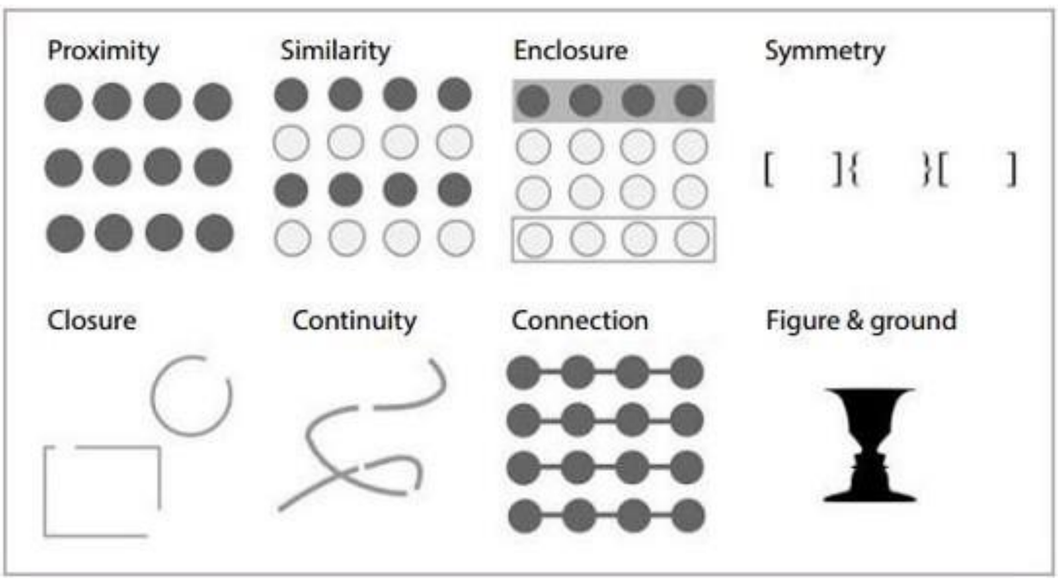


***Figure 12.*** *Gestalt principles [5]*

# 4. Conclusion

This document is presenting some basic guidelines for VR content creation, which are based on the properties of VR equipment and existing interaction modalities (head mounted displays and controllers). The guidelines are presented based on a number of perspectives, such as ergonomics of interactions, properties of human vision and image perception, but also considering the limitations of VR technology as compared to movement in natural space. The goal of the document is to provide guidelines for creation of educational VR content in the scope of the Erasmus+ VTech project.

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