# Interactive animations for user interfaces

## Creating a model for how they should be constructed

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**ABSTRACT**

This paper explores the role of animations in user interfaces. As computers become more capable, there are fewer limits to what animations can be produced. Interaction designers do not have free reins however, as they should still consider how users experiences these animations. As extensive use of animation in interfaces is relatively new, there are few clear guides for how the animations should be constructed. This literature review will for that reason look at the research performed in the field of animation to see if there are some guidelines that can be drawn. The sources were drawn from the field of interaction design, and also from the field of cartoon animation and human physiology, to widen the perspective and get new insights. A case study was also carried out, that utilized the knowledge found in the literature to test these aspects of animation. The findings from the literature and the case study was that animations can be composed in endless combinations and are also highly context dependent, making it difficult to create explicit guidelines. There are however common themes that have to be addressed when creating animations. The Glue Model was created to summarize these themes, where it compares four characteristics of glue to aspects of animation. This model helps the interaction designer to get into the right mindset for making animations.

**KEYWORDS:** Animation, transitions, composition, timing, interface design

## 1. INTRODUCTION

A trend in interface design is to use animation as a method for explaining interfaces [1, 2]. The computational power of computers has increased exponentially over the last 25 years, as stated in Moore's law. The result of this is that computers are capable of producing animations with few restrictions. Animations are nonetheless to a large degree restricted to the OS and consumer applications, with it being used less in business applications. Animations have become especially important in mobile interfaces. The reason is that content is being viewed through applications, which gives great control in all aspects of a user interface. Compared to viewing content in a web browser through hyperlinks, where the transitions from one screen to the next often is abrupt, applications gives the opportunity for more fluid transitions. Screen real estate is also valuable on mobile interfaces. Mobile displays can rarely display all information needed on one screen, leading to the need of switching between screens. Desktop computers on the other hand have the possibility of displaying more content at the same time, for example multiple programs. The increase in computational power is something mobile phones also has experienced over the last few years with the rise of smartphones, but there are still limitations to what they can do computationally because of their limited size.

Software companies that develop operating systems make guidelines [2, 3] to describe how animations should behave in their ecosystem.

These guidelines are made both to make sure that what is being developed fits with everything else in the platform, and also a way to transfer knowledge about what they think good design is. However, these guidelines often get interaction designers just a part of the way. They can only show a limited amount of examples, which have to be presented broadly. This means that the interaction designer often will have to find inspiration elsewhere. This usually comes from books, websites where interfaces are presented, or by analyzing what has been done in other interfaces. The pitfall here is that many of these sources focus on what is cool, pretty and trendy, with less focus on how the animation enhances usability. Most of the information available here is based on anecdotal evidence and not clear research, making it difficult to evaluate.

The use of animation in user interfaces has also gotten critique. An example from the early days of the internet is how Flash was used to «jazz up» a web page to make it more appealing. Many times the end result was that the animations only reduced usability [4]. Animations in mobile user interfaces has also gotten critique, with the result that some users want to turn off animations completely. A Google search (12.11.15) was performed on the two main mobile operating systems, iOS and Android, to demonstrate this point. The search words “turn off animations ios” got approximately 6 000 000 results, and “turn off animations android” got approximately 14 000 000 results.

The article will first look into why animations can be beneficial to user interfaces, and then go into how these animations should be designed.

## 2. METHODS

The basis for this article is a literature review, with sources from reports, articles and web-sites. Articles on animation for interfaces where mostly found on Association for Computing Machinery, ACM. The focus was to find articles that dealt with how animation affects the user’s experience of an interface. Articles that described tools for helping programmers implementing animation were therefore not considered.

The articles from ACM mostly dealt with specific aspects of animation and why that aspect was beneficial. Other sources were for that reason sought, to get a more comprehensive view of the area. Information on cartoon animation were found, because a lot of what is considered good animation practice for user interfaces is taken from that field. Cartoon animation also has a much longer history than animation in user interfaces, so they will possibly have already dealt with issues that might arise in user interface animation. Articles that dealt with how the human eye reacts to motion were also found, as movement is one of the fundamental aspects for a lot of animation.

Complementary to this literature review an interaction design project with an education application called Ace was performed. The animation principles found were incorporated in the application, which were then user tested on fellow students to see if the principles worked as the research implied. Another focus was to see if there were other aspects that should be considered that where not detailed in the research. The findings of this case study is presented at the end of this article.

## 3. THEORY

### 3.1 Defining animation in user interfaces

When defining what animation in user interfaces is it can be useful have an overview of animation in general. At a broad level animation can be described as a sequence of static images that change rapidly enough to create an illusion of a continuously changing picture [5]. This is true for animation in all media. When narrowing the definition down to only animation in interfaces there are however many different definitions. In these there are varying degrees of what kind of dynamic changes are accepted as animation [5-8]. Some authors base their definition of animation on movement, as in change of position [5, 9]. Others have a more wide view of it, but they rule out transition effects as dissolves, zooms and wipes [8]. Lastly there are some that don’t focus to rule out any types of animation types, but instead look at the purpose of animation, which is to help the user perceive

changes over time, by presenting a series of varying images dynamically [6]. This article will make use of this broader perspective of animation. This means that change of position, colour, size, shape, opacity and so on is included. It will now be of interest to investigate what effects animation has on an interface, and from this find out what functions animation can have.

### 3.2 The effect of animation in user interfaces

There are many different theories about what effects animations in interfaces can have for the user. The way to best understand them is to consider an interface where there are no animations, so the system changes instantly from one state to the next. Chang and Ungar notes that in such interfaces the causal connection between the states is not immediately clear for the user [10]. This means that they will have to use time on reorienting themselves, as there were no visual cues to indicate what what's happening. Robertson et al. stated that adding animations will reduce the cognitive strain of the user, by shifting some of the user's cognitive load to the human perceptual system [11]. A way animation does this is by tapping into the perceptual phenomenon of object constancy, so that an object is perceived as the same even though it is changing in size or position [12]. Examples of this can be of files moving fluidly from to show that they are being transferred and apps expanding to show that they are being opened.

Small and Baecker stated that «animation can help us review the past, understand the present, and describe the future» [5]. From this statement they constructed a taxonomy of functions an animation can have, shown in Table 1. This taxonomy answers questions the user might have to the functions of an interface, and understand what they have done, what they should do and where they should go.

Gonzales found that when users got continuous animated feedback from a system, they performed better when doing tasks on it [6]. She therefore theorized that animations can help the user to develop a more appropriate mental model of the task they are doing. Bederson tested people's abilities to recall the position of family members in a family tree, where one tree had abrupt changes from one state to the next and the other tree had animated transitions [13]. He found that animations were beneficial when the users were asked to reconstruct the family tree, as they had notably fewer errors. From this he theorized that animations can help users to better recall spatial positions.

| | |
|---|---|
| **Identification:** | What is this? |
| **Transition:** | From where have I come, to where have I gone? |
| **Choice:** | What can I do now? |
| **Demonstration:** | What can I do with this? |
| **Explanation:** | How do I do this? |
| **Feedback:** | What is happening? |
| **History:** | What have I done? |
| **Guidance:** | What should I do now? |

*Table 1: Taxonomy of animation*

Animation can also be used as a tool for grabbing attention. For interfaces that are in the periphery of the user, animations can draw attention to changes in the state of this interface [14]. Some researchers state that such animations can lessen the performance of the users on their main task, and should therefore be avoided [15]. Others state that animations can be constructed so this is not the case, for example by using a slow fade for less important information so it draws little attention [14, 16].

### 3.3 Cartoon animation

It is important to consider cartoon animation when working in the field of user interface animation, as much of what is considered good practice in the field has been taken from techniques developed for cartoon animation [1, 5, 10]. One reason behind this is that cartoons focus on conveying ideas as clearly as possible.

One principle they use for this is staging, where camera position, lighting, motion and timing all work together to to help the viewer focus on the idea being conveyed [9]. An example of staging can be to position the camera so the characters are in silhouette so their movement can be clearly seen. Another is to limit movement to only what the viewer should look at, so if there are less important characters in the frame their movement is kept to a minimum to reduce visual noise.

Cartoon animation has taken inspiration from the real world as a means to make the viewer believe a story in an imaginary world [17]. They use different techniques to make the imaginary world feel more real, by for example simulating physics. One way of doing this is the acceleration and deceleration of cartoon characters to mimic inertia. Taking inspiration from this in UI design can therefore be a way to make the user believe that elements on an interface are tangible entities, which they can interact with and manipulate [10].

Cartoons are also engaging, with the viewer being completely absorbed into it's world. Chang and Ungar noted that this can be of benefit to user interfaces, so that the user's attention is only on the task at hand [10].

The differences between cartoons and user interfaces has to be taken into account. A cartoon is a passive medium where the animation will play out independently of the user's actions, and a user interface is an interactive medium. These differences is also reflected in the context they are used in, as user interfaces most often are used for performing a task while cartoons are for enjoyment. Some implications of these differences will be detailed later.

The purpose of animation in user interfaces and aspects from cartoon animation has now been examined. This knowledge will be applied when defining how the animations should be constructed. Animations are built up of two parts, composition and timing, which will now be detailed.

### 3.4 Composition

Composition describes the way an object changes. This implies both the start and end states, and the way the object transitions between these two states. Consider the figures below, that show the animation of pause buttons in two different interfaces. Figure 1 shows the pause button in Apple Music and Figure 2 shows the pause button in YouTube. The start and end state for both of these icons are the same, but the way they handle the transition between them is different. The first uses crossfading, where the start state fades out while the end state concurrently fades in. The second works by morphing the shape of the icon, so it fluidly changes from the start to the end state. In morphing the designer has to pay special attention to the minute details of the morph, so the transition is presented clearly [18].

*Figure 1: Crossfade*

*Figure 2: Morphing*

| Communicative function | → | Animation type |
|---|---|---|
| Different context | → | Change of place |
| Different value | → | Change of size |
| Different status | → | Change of color |
| Different importance or urgency | → | Change of color |
| Different function | → | Change of shape |
| Different referent | → | Change of place |
| Salience | → | Blur |

*Table 2: Communicative functions linked with appropriate animation types*

What kind of start and end point that should be chosen depends on many aspects. Novick et al. [7] analyzed different types of user interfaces, and from this drew out seven types of animations and also seven types of communicative functions they could have. A matrix was then created using this as the axis, where the appropriateness for the different animation-functions were estimated. The types of animation-function pairs that were found most appropriate is shown in Table 2.

Gonzales [19] noted that the task domain should also be considered when evaluating what type of characteristics an animation should have. This can then be used to determine if it is appropriate or not. Chang and Ungar also stressed this point when they compared the different purposes of user interfaces and cartoons [10]. They found that things that where appropriate in cartoons could be inappropriate in user interfaces. If something don't behave as expected in a cartoon, it can be a way to surprise the viewer. This fits to the cartoon context, but would not be appropriate in an interface since the user would not understand why the system responded this way. They also advised against wacky animations, as they stated that this would not be appropriate in an interface context.

Transitions in user interfaces can also be compounds, where different elements transform at the same time or in succession. Compound animations can be used to convey more complex ideas, since there are more elements to work with. They can however be perceived as incomprehensible when constructed carelessly, since there is too much happening at the same time [5].

### 3.5 Timing

Timing, the duration of the different elements of an animation, is important to take into consideration. The user has to be able to perceive what is happening to understand the change of state in the system [13]. This puts limitations to how fast an animation can play out. The drawback of having a slower animation is that it takes time, which can lead to the user having to wait before they can perform the next operation. Chang and Ungar therefore makes the point that the user should be given the control to use the system to perform the next action immediately, without having to wait for the animation to finish [10]. Mattes et al. suggested fixing this issue by giving the user the option of disabling animations [20].

Mattes et al. found that animations used to visualize changes in the state of the user interface the duration could be quite short, around 300ms [20]. However, the duration could be vastly longer in animations that had to guide the user's

attention to a certain area of the screen and then trigger a cognitive process; in one of their experiments the animation lasted 5 seconds. For these types of animations they recommended using cognitive modeling programs, to get a prediction for the duration. The correct duration can also be dependent on the user's experience with the interface as well [13].

The perception of how long an animation takes will also be based on how it is composed [21]. This means that two differently composed transitions with equal length can be experienced by the user as having different durations.

Using the correct timing is also important in cartoon animation. Here animations with the same movement can convey completely different ideas, depending on how long their duration is [17]. The nuances here are important to consider, to make sure the animation communicates properly.

Although animation in interface design has multiple positive aspects, the human physiology poses some limitations related to animation. These limitations should also be considered when developing the interface, so it fits the user.

### 3.6 Physiological limitations to animation

With the update to iOS 7 in 2013, a lot of users reported that they felt motion sickness when using their phones [22]. The reasoning was that the operating system now relied on extensive use of animation and transitions. The biggest triggers of the motion sickness seemed to be full screen transitions, and animations that tried to simulate the real world. Examples of this were parallax of the wallpaper to mimic depth, and zooming into apps to simulate traveling into the world of the application. These animations gave the user's visual system input, but the vestibular system did not get corresponding signals, leading to motion sickness. The consequence of the reports was that Apple issued a way to turn off certain animations in the first update of iOS 7 [23]. This is part of the «Accessibility» settings, where users with special needs can customize their phone to fit these needs [24].

How the human eye works, especially details related to the way it reacts to display elements that are either static or moving, is also of importance when working with animations. Here the concepts of saccades and smooth-pursuit must be understood. When looking at a mostly static scene the human eye moves rapidly and erratic from place to place, to take in the most important element of the scene. These motions are called saccades. When the human eye is tracking a moving object however, it goes into a state called smooth-pursuit [25]. In this state the eyes follow the object continuously. The eye can follow objects that move up to 30 degrees per second of it's field of view, and if the movement is faster than this it has to perform catch-up saccades. Here the eye has to skip ahead to catch up with the moving object. There are also limitations to how many objects it can track at the same time. There is some debate to the number of objects it can track, but there are consent that the number of objects it can track is based on how fast they are moving [26]. This means that the faster the objects move, the fewer objects the eye can track. Alvarez and Franconeri found that the maximum number of objects the eye could track was 8, and the speed the eye could track one moving object was 16 degrees per second. These aspects puts limitations to how many objects can move at the same time in an interface, and also how fast they can move while still being trackable.

## 4. DISCUSSION

### 4.1 Why animation is beneficial

The main benefit of animation in user interfaces is that takes the user interface from something that is static and transforms it to something dynamic. By being dynamic the interface reduces the cognitive load of the user, as they can follow the shift from one state to the next seamlessly. This is helpful, as when working with an interface in the present, you have always come from a place, the past, and you want to go somewhere, the future. Figure 3 visualizes how a user perceives an interface without animations. The states are separated from each other, as the interface transitions abruptly between them. It can therefore be difficult for the user to answer


*Figure 3: Perceived interface without animations*

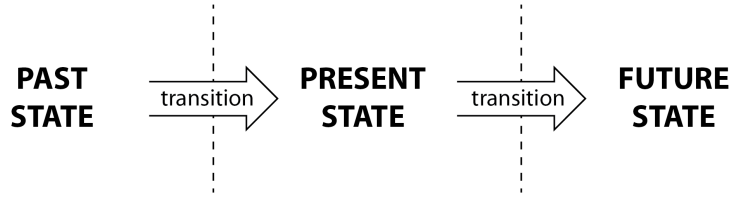


*Figure 4: Perceived interface with animations*

the question posed by Baecker and Small: « From where have I come, to where have I gone?». Figure 4 shows an interface with animated transitions between the states. This leads to the states not being detached from one another, but instead connected by the transitions between them.

Being dynamic also makes a user interface more analogous to the real world, where something goes from one state to the next gradually and very rarely instantaneously. Animations can therefore help giving user interfaces more appropriate and expected responses, by becoming more similar to things humans encounter in the real world. Bederson found that animations helped users to better remember spatial positions, and were able to rebuild the information at a later point in time. This helped users not view the interface as fragmented states, but as a unified whole.

### 4.2 Implications for interaction designers.

When looking at the different articles there are few guidelines designers can follow to create good animations. However, there are factors that should be considered when deciding if an animation is appropriate or not. The type of task or action the user will do has to be analysed, and from this the designer can decide what they want to communicate with the interface. An animation type can then be chosen, and the designer can look at it's characteristics to see if it communicates clearly.

The task domain should also be considered, as an animation that is fitting in one domain might be inappropriate in another. Most of the research performed about animations were done in the 90's, and the research stresses the point that user interfaces are made for performing a job. This put restrictions on how inventive the animations should be, and Chang and Ungar noted that wacky animations were not appropriate for user interfaces. However, what user interfaces can be used for has changed since then, especially with the rise of smartphones. A lot of the apps for smartphones can be used for enjoyment on their own, without fulfilling a specific task. This can change the way animations are used, as they can now possibly be used as entertaining elements in their own right. These new applications can erase the divide between computer programs, games and cartoons, where the animation style they use can be a part of this. In the guidelines for Google's Material Design animations have gotten their own chapter It stresses the point that animations can be delightful on their own right, and by doing this it can increase the experience as a whole [27]. An example of such an animation can be the play button from YouTube described above. It might not communicate anything more than the one from Apple Music, but it can be a part of shaping the way the user experiences the system.

When it comes to more complex animation types, there has been done little research on how this affects the user's interaction with an interface. Some aspects should however still be considered. Many researchers advised to keep an animation's complexity to a minimum, to not confuse the user of the system. Mattes et al. performed research on animations that were triggering quite complex cognitive responses [20]. A consequence of this was that the animations had to be quite long, up to five seconds, for the user to understand what was happening. From Bederson's point of view this duration is too long, as the total system response time will seem too slow for the user [13]. Chang and Ungar agrees with this, and adds that users should not feel that they are waiting for an animation to play out [10]. Having certain elements change concurrently might be a way to reduce the duration of such animations. However, this has to be done very carefully, as there are constraints to how many changes the human eye can track at the same time. The maximum number Alvarez and Franconeri found was 8, but it will possibly be lower in real life use. The reason for this is that in their experiment the user only had a single task, and that was to follow moving objects. When using an interface the attention of the user might be somewhere else, so they might miss a movement. Taking inspiration from traditional animation could be a way to evaluate the animations, to see if there are elements that are conflicting over the user's attention. If they are the designer can then see if the animation should be composed in another way, for example by moving objects together so they are interpreted as one entity, or by playing out movements in succession.

An aspect of animation the designer has to consider are instances where some users want to turn off animations because they get motion sick from them. A solution here can be to give the user control to reduce the animations. However, an ethical discussion can be had on if it is right to add animation types that a certain percentage of the population cannot watch. An alternative could be to find other animation types that are appropriate for everyone. Another issue is situations where some users find the animations annoying. A solution here can be to give the user the ability to override the animation, so they can perform the new task immediately. If there is a significant portion of the users that want to turn off the animation it can also be a sign that either the duration or composition of the animation is inappropriate for the task. Here it can be appropriate to investigate alternatives for this animation. If the end result is that the user is given the option to turn off the animation completely, the start and end state should still be able to communicate what happened on their own.

Animations that are made for drawing the attention of the user to some feature of the system should be applied with great care, as they can reduce the performance of the user if not done correctly. The type of animation should here be chosen based on the level of importance of the information. If the animation should only be performed once or be in a loop can also be decided on based on this.

### 4.3 Case study

Complementary to this article work on a mobile application called Ace was performed in PD9. The application is made out of short quizzes on the curriculum of student courses. Appropriate mapping of large amounts of information and also giving adequate feedback are integral parts of the application, so the use of animation was expected to be important for communication. When developing the Ace application several principles of animation were tested, for example: timing, composition and appropriateness of animation type.

It was found that timing had a lot to say for how the users experienced the interface. Changes in duration of 50-100ms made great differences in if they felt it was rushed or too slow.

When working with compound animations user testing and many iterations where a key part of making the animations work well. The start and end points, the different components and their movement, and the order they should be played out in had all to be taken into account. This was done to make sure the animation conveyed its message, and also did not feel dragged out.

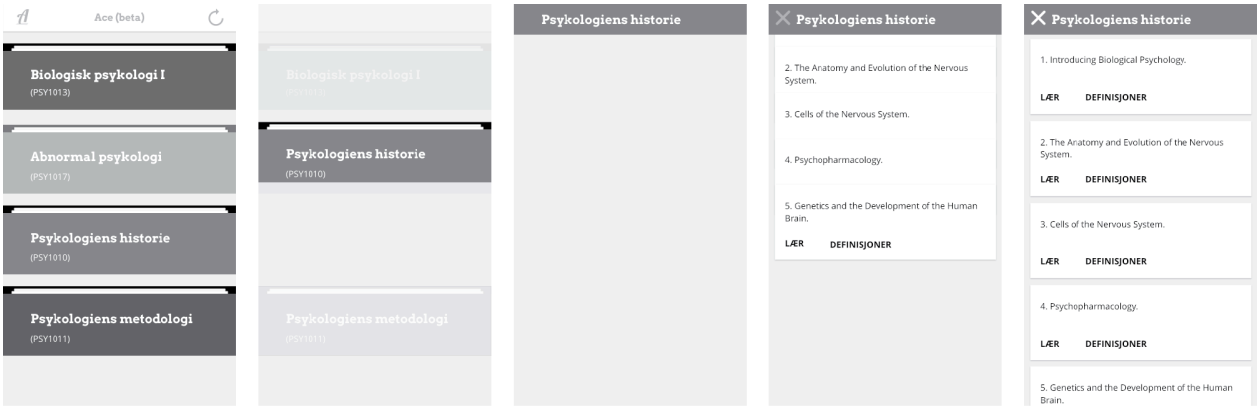


*Figure 5: Steps of a complex animated transition*

An example of such a complex animation is shown in Figure 5, where a course is selected and opened. The wanted communication of the animation is the opening of a file folder, where the content is then laid out. The start and end states are simple and clear, but between these states several actions happen. After one of the courses has been selected it starts moving up to become the header, as it simultaneously shrinks to remove the lower line of text. The other courses also start fading out, so the don't draw away the attention from the selected course. When the header reaches the top there is a short delay, to signalize that this action has ended. The contents of the course then come out from underneath the header, while the X-symbol fades in.

Although the composition of this animation was complex to create, it seemed like the users did not feel overwhelmed. The animation felt simple as the point of focus first was on the folder moving up and then the files moving down. This meant that the other aspects of the animation, the fading elements and the change in size, did not take unnecessary attention.

Another insight was that after the users had become acquainted with the interface some felt some animations were taking too long. They had not commented on these animations earlier, so they likely now understood the communicative function of the animation. An interface can't know if the user experiences an animation as too short or too long, this might be a sign that this animation is not appropriate in this case. An animation that could clearly communicate the function over a shorter period of time could be more fitting. Another alternative could be to use a long animation when the user first experiences the interface, to communicate the function clearly. After this a shorter animation is used, so it does not feel dragged out. A potential problem here can be that the user does not notice the animation the first time, and therefore the communication is lost in the later instances as well.

Change of opacity was an animation type not listed in the table of Novick et al. It was tested, and it seemed that reducing opacity of an object worked for communicating that it was inactive, and also as a way to guide the focus of the user toward active areas. Therefore it seems to have similar communicative properties as change of color, as it does communicate a change of status and the importance of an element. One can argue that a reduction in opacity is just the same as changing the color to a lighter and less saturated version, making it essentially the same thing. It might be smart to keep them separated anyway, so the designer knows what tools they have.

Having animations behave as expected was also found to be an important aspect. Mobile operating systems have certain ways of navigation that are used throughout the system to give it unity, and to follow these guidelines

might therefore be appropriate. An effect of this is that an animation that is predicted to be suitable for a task, as it in theory should communicate clearly, can be inappropriate since there is another form of animation the user expects to encounter. This other form of animation will here be more appropriate, even though it might be deemed as less communicative. An example of this is the complex animation described above, which was predicted to communicate clearly. However some users expected a slide to left which is used throughout the OS, so this expected navigation model was deemed as more fitting.

### 4.4 The Glue Model

There are many considerations that need to be taken when creating an appropriate animation for an interface. The range of animations that can be created is vast, so giving guidelines describing in detail how different animations should be made is not fitting. There are however common themes that have to be addressed when creating animations, and The Glue Model will in four points present these themes. As its name implies the model is based on the characteristics of glue, and will apply these characteristics to aspects of animation in interfaces. This model is created to give associations, as a way to remember the aspects of animation.

*1. It connects elements*
Glue can take two different elements, and join them together so they form a new whole. Animations in an interface work in a similar way, as they join the states of the interface together. This way the states don't feel detached from one another, but instead connected. The user can therefore better understand what is happening, as the link from one state to the other is apparent. Connecting the states can also help the user to make a mental map of their positions, helping the user find them later.

*2. Right glue for the right job*
There are many different kinds of glue, and each of them work for only a few different materials and purposes. With animation there are many different animation types to choose from, but they don't fit for all purposes. Aspects to consider when selecting an animation is what it should communicate, and also the task domain of the interface it will be applied in. Using the same type of animation for the same type of task or communication is also preferable, so the interface behaves dependably.

*3. Less is more*
More glue does not mean a stronger joint, and in most cases a little glue goes a long way in providing a strong joint. With animations the designer might be tempted to try to convey a lot of information in a complex animation. However, this is of little use if the user does not understand the animation, leading to the information being lost. Animations should be reduced to as few elements as possible while still conveying the message, so the user is not confused by superfluous elements.

*4. Testing the joint*
When adhering critical structural elements with glue it is important to test the joint to examine if it can handle the forces it will be put under. It is the same way with animations, where testing an animation on users is the only way to see if it conveys the message in an appropriate way.

## 4. CONCLUSION

Animations can be applied to interfaces as a tool for visualizing changes in the interface and communicate these changes to the user. However, this only works to a full extent if the animations are constructed correctly. The Glue Model was created to summarize the aspects of animation that has to be considered when creating and evaluating animations for interfaces. The model compares four characteristics of glue with aspects of animation. These characteristics are that animation connects states, the right animation should be used for the right job, low complexity is preferable and that is it important to user test the animations. By using this model the interaction designer can get into a mindset for appropriately constructing animations.

## References


1. Bloq, C. *Will animation be the big UI trend of 2015?* [cited 2015 11.10]; Available from: http://www.creativebloq.com/animation/will-animation-be-big-ui-trend-2015-21514144.
2. Google. *Meaningful Transitions*. Material Design Guidelines; Available from: https://www.google.com/design/spec/animation/meaningful-transitions.html#meaningful-transitions-visual-continuity.
3. Apple. *Animation*. iOS Human Interface Guidelines 2015 [cited 2015 2.11]; Available from: https://developer.apple.com/library/ios/documentation/UserExperience/Conceptual/MobileHIG/Animation.html.
4. Nielsen, J. *Flash: 99% Bad*. 2000 [cited 2015 12.11]; Available from: http://www.nngroup.com/articles/flash-99-percent-bad/.
5. Baecker, R. and I. Small, *Animation at the interface.* The art of human-computer interface design, 1990: p. 251-267.
6. Gonzalez, C., *Animation in user interface design for decision making: a research framework and empirical analysis.* 1995.
7. Novick, D., J. Rhodes, and W. Wert. *The communicative functions of animation in user interfaces*. in *Proceedings of the 29th ACM international conference on Design of communication*. 2011. ACM.
8. Stasko, J.T. *Animation in user interfaces: Principles and techniques*. in *User Interface Software*. 1993. John Wiley & Sons, Inc.
9. Lasseter, J. *Principles of traditional animation applied to 3D computer animation*. in *ACM Siggraph Computer Graphics*. 1987. ACM.
10. Chang, B.-W. and D. Ungar, *Animation: from cartoons to the user interface.* 1995.
11. Robertson, G.G., J.D. Mackinlay, and S.K. Card. *Cone trees: animated 3D visualizations of hierarchical information*. in *Proceedings of the SIGCHI conference on Human factors in computing systems*. 1991. ACM.
12. Benjamin, M., *Miller-Keane Encyclopedia and Dictionary of Medicine, Nursing and Allied Health.* Philadelphia: Saunders, 1997.
13. Bederson, B.B. and A. Boltman. *Does animation help users build mental maps of spatial information?* in *Information Visualization, 1999.(Info Vis' 99) Proceedings. 1999 IEEE Symposium on*. 1999. IEEE.
14. Matthews, T., et al. *A toolkit for managing user attention in peripheral displays*. in *Proceedings of the 17th annual ACM symposium on User interface software and technology*. 2004. ACM.
15. Zhang, P., *The effects of animation on information seeking performance on the World Wide Web: Securing attention or interfering with primary tasks?* Journal of the AIS, 2000. **1**(1es): p. 1.
16. McCrickard, D.S., R. Catrambone, and J.T. Stasko. *Evaluating animation in the periphery as a mechanism for maintaining awareness*. in *Proceedings of the IFIP TC. 13 Conference on Human Computer Interaction*. 2001.
17. Thomas, F., O. Johnston, and F. Thomas, *The illusion of life: Disney animation*. 1995: Hyperion New York.
18. Vronay, D. and S. Wang. *Designing a compelling user interface for morphing*. in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2004. ACM.
19. Gonzalez, C. *Does animation in user interfaces improve decision making?* in *Proceedings of the SIGCHI conference on human factors in computing systems*. 1996. ACM.
20. Mattes, L., et al., *Acceptance and speed of animations in business software*, in *Human-Computer Interaction–INTERACT 2011*. 2011, Springer. p. 438-441.
21. Huhtala, J., et al. *Animated UI transitions and perception of time: a user study on animated effects on a mobile screen*. in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2010. ACM.
22. Grannell, C. *Why iOS 7 is making some users sick*. 2013 [cited 2015 11.10];

Available from: http://www.theguardian.com/technology/2013/sep/27/ios-7-motion-sickness-nausea.
23. Grannell, C. *How Apple's iOS 7.1 finally quelled users' motion sickness*. 2014 [cited 2015 11.10]; Available from: http://www.theguardian.com/technology/2014/mar/13/apple-iphone-ipad-ios-71-motion-sickness.
24. *Accessibility, iOS*. Available from: http://www.apple.com/accessibility/ios/.
25. Schanuel, I. *On Motion Sickness and the Handling of 2D UI Elements in Virtual Reality Environments*. 2013 [cited 2015 29.09]; Available from: http://www.gamasutra.com/blogs/IslaSchanuel/20131212/206899/On_Motion_Sickness_and_the_Handling_of_2D_UI_Elements_in_Virtual_Reality_Environments.php.
26. Alvarez, G.A. and S.L. Franconeri, *How many objects can you track?: Evidence for a resource-limited attentive tracking mechanism.* Journal of Vision, 2007. **7**(13): p. 14.
27. Google. *Delightful details*. 2015 [cited 2015 06.12].