Considerations on projection screens and home-cinema

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This text was first published in Portuguese by Lusoscreen on January 24’th 2019

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Introduction

People in general are usually careful when choosing the characteristics of a projector. We take into account the number of pixels, its brightness, the contrast ratio and a myriad of other specs. But the next step, the projection screen, is left to chance, using price as the main criterion.

When we get around to purchasing the projector, our goal is to have an image with good quality and for that we need (among other things) good contrast. However, a projector can only output light, you cannot project black. Because of this, you cannot count on the projector alone to give you deep blacks on a projected image.

Regardless of how much contrast a projector has, the maximum level of black that can be achieved in the projected image is that which the screen can give you. *As such, although there is no picture without a projector, for the final result the screen is as important or even more important than the projector itself.*

From among all types of possible screens (automatic, motorized, fixed, tensioned, etc.), the projection surface is the most important part and it should have special characteristics so that the projected image has quality.

People who can have a room dedicated to home cinema, because they are unaware of the existence of technical screens, usually paint the walls and the ceiling with dark colors. Some go a bit too far and line everything in black velvet. This is because when we project light on a screen, that light will be reflected to the walls and ceiling which, in turn, will reflect it back onto the screen. This reflected light will illuminate areas of the screen that should be dark. And if the screen is white, the areas that should be black become gray, making it impossible for the black areas of the image to actually become black and ruining the result.

However, if the projector has low contrast, even if the walls and ceiling are dark, the image will remain poorly contrasted.

That is why some manufacturers have developed technical screens known as "ALR", "High contrast", etc. which aim to substantially improve the projected image without the need to darken the walls or ceiling, raising it to the level of a true cinema.

An informed person, when wanting to invest in something, seeks information from specialists. Nowadays, the internet is an extraordinary source of information. But, unfortunately, most of the information you find on the internet is from salesmen whose interests are not always clear, or from pseudo-experts who just want to get attention.

There is an abundance of people who do reviews, who measure gains and contrasts, who sell calibrations, and so on... they measure everything rigorously (or not!), but they always forget some fundamental elements (usually those that are less relevant for their purposes), without which their measurements have little value and may even mislead their many unsuspecting followers.

This document will try to explain a few basics of criteria to take into account when choosing a screen for a home theater.

There are four main aspects involved in the image quality of a home theater. The projector and the screen are the ones that are usually taken into account (for many, less informed, just the projector alone). But equally important, is the way our eyes and our brains perceive the images.

We should also take into account the conditions of the room, size, shape, light sources, etc. You can not expect to have a movie theater in a space that is hardly enough for a TV, just as one does not buy a car (however good it may be) to use in the pool. In this highly specialized subject, the help of a credible professional is paramount.

We will look at some points where the sensations of the eyes and the brain invalidate and contradict the criteria of choice obtained on the basis of simple measurements.

White perception

We can do a simple experiment by projecting an image of a white square on a black background, on a white screen, in a dimly lit room. Then repeat the operation on a negative gain screen (using normal gray screen or a technical screen).

Visually, when we do the two projections at separate times, our eyes tell us that the image brightness (the whites) is exactly the same.

We can even take pictures of both screens and we will see that the whites will continue to look equally white on both screens.

But if we take a small sample from one of the screens and place it so that it takes half of the white square that is being projected on the other screen, we see that the white being projected on the white screen is visually brighter than when projected on the screen with negative gain.

So the immediate and simplistic conclusion is that whites are whiter on the white screen.

This is not incorrect. In absolute terms they are, but visually, which is what interests us, we only realize that they are whiter when we see them side by side.

So what happened? Our eyes always adapt to circumstances. Like the automatic diaphragm of the camera, our eyes close their iris more when we look at the white screen and open it more when we look at the gray screen. In practice the light that enters our eyes, just like the camera, is exactly the same in both cases, and the whites are seen in a similar way, although they are not the same in absolute terms.

In addition, the added contrast that a dark screen introduces, also greatly influences our perception of white.

In order to have a better idea of the influence of contrast on our perception of white, let's look at image 1:

Image 1

Even when viewed at the same time, a situation which is less ideal than the previous one, the white squares on the right and left of the image look very similar. Sometimes the right one may even look whiter due to the lack of contrast of the left image and the higher contrast of the right image.

However if we remove the dark backgrounds leaving only the white squares (Image 2), we will see that the tones are noticeably different: the one on the right is actually much darker.

Image 2

A more correct conclusion is that the gain of the screen alone is not a sufficient criterion for the choice, being of little relevance in relation to other characteristics, namely contrast.

As we can see from images 1 and 2, it is often preferable to lose a percentage of the white level if this allows us much deeper black levels. In practice the image gains dynamic and depth, with whites perceived much whiter than they are in absolute terms. As the diaphragm of our eyes adapts, the brightness of a negative gain screen may appear to be equal, or even superior, to that of a screen with gain 1.

This is why it is not a good idea to try to compare screens using small samples. Doing this induces us almost invariably in error, prompting us to choose the wrong screen. Moreover, in a small sample we don’t have indications about angles, spot, etc ... You can only get a true notion of the quality of a screen when using the full screen.

In the case of a screen with positive gain and a dark surface, the difference with respect to the white screen is further accentuated. Not only do blacks get deeper, but whites become even whiter, so that the image can rival a giant TV for a fraction of the price.

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When we analyze more complex images the perception of whites and blacks becomes even more complicated: the whole visual scene is interpreted by the brain rather than by the eyes. It "sees" the image in light of all the experiences and adaptations made over millions of years of our evolution.

The "illusion of Cornsweet," a pioneer in the study of visual perception in the 1960s, shows us clearly and strikingly how the brain interprets images differently from what they actually are (Image 3).

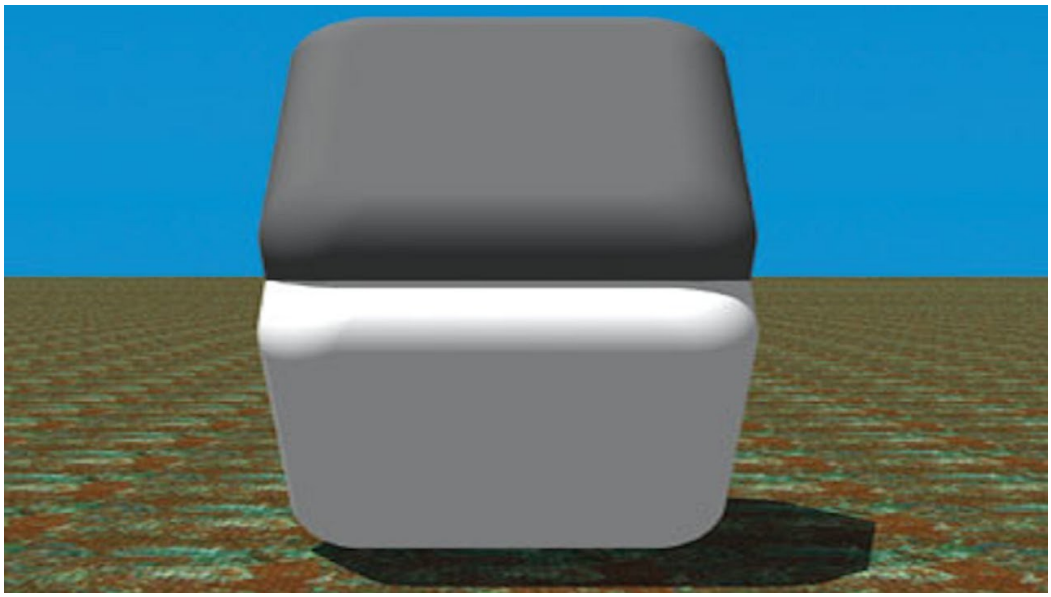

Image 3

The upper face of the cube looks black and the underside looks white, but if we cover the union of the two faces we see that they have exactly the same shade of gray (Image 4).

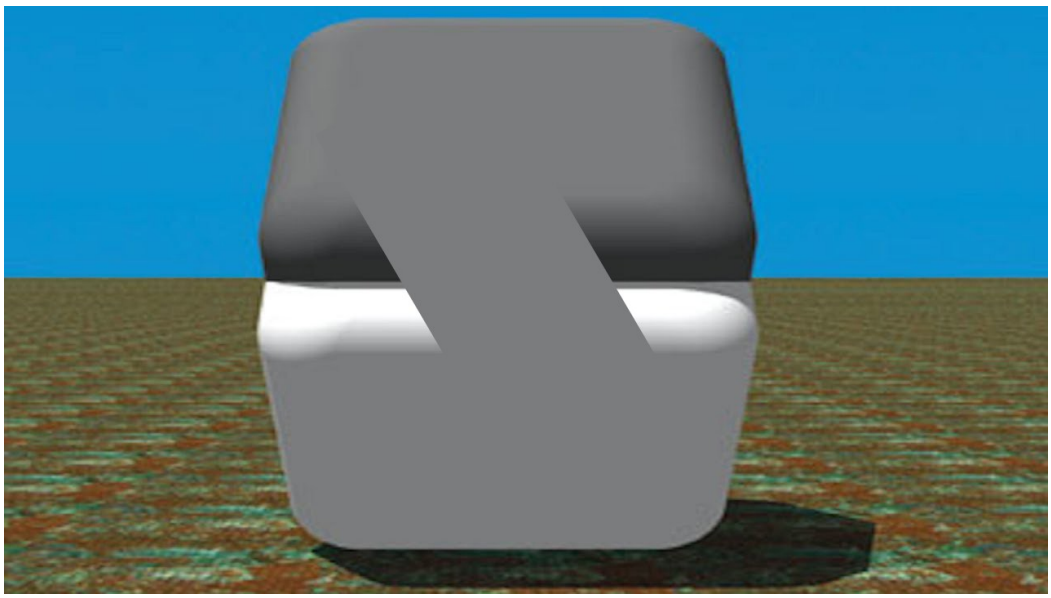

Image 4

Another equally impressive example given by an American neurologist, Edward H. Adelson, Professor of "Vision Science" at MIT, in 1995 can be seen in image 5.

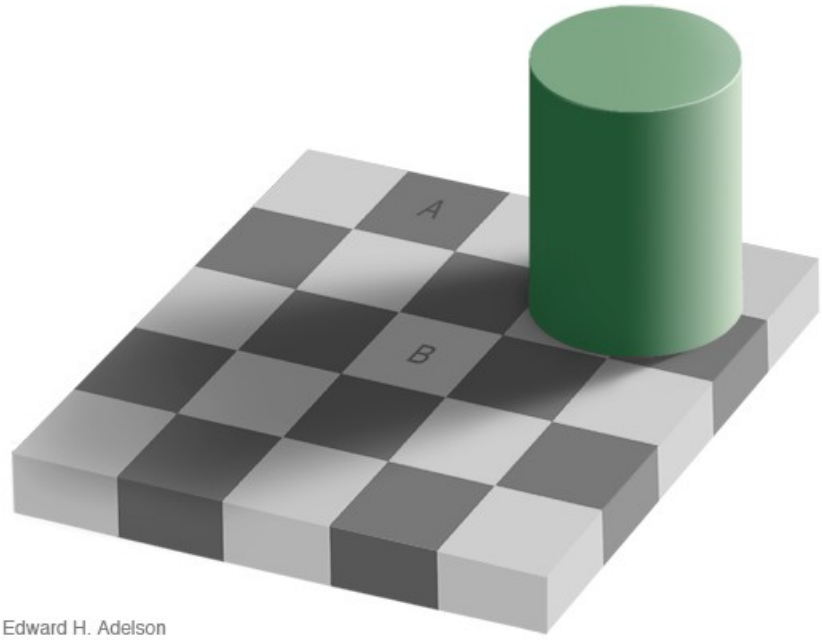

Image 5

Squares A and B have exactly the same shade of gray (Image 6).

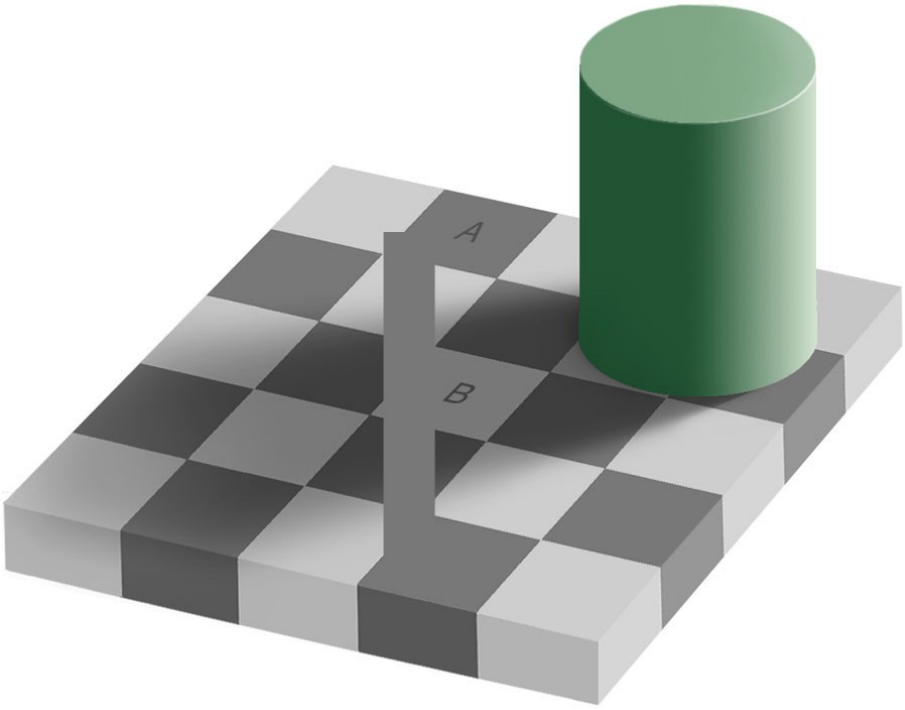

Image 6

Our eyes deceive us in such a way that even the solid color bar placed on top of the image to demonstrate that the squares have the same tone sometimes appears to have a gradient.

Unfortunately, many people make their screen choice based on the comparison between small samples. The screen that appears to reflect more light (more gain) is usually the chosen one.

As we've seen, our eyes can easily "see" vastly different shades of white as being the same. Therefore the criteria can no longer be simply the gain of the screen, other more important factors must be taken into account, such as contrast.

Contrast

The contrast in a projected image is, as has already been said, one of the main characteristics for the quality of that image. In a white screen only in very exceptional situations we will have deep blacks.

On a dark screen, from the outset we already have blacks that are as deep as the screen is dark. *It is worth remembering that projectors only output light, you cannot project black.*

Okay, so we know that the reflected light from the walls and the ceiling will ruin the black areas of the image, but at least the areas that are already white will receive a little boost, correct?

Again, in absolute terms we can imagine that, yes, but our eyes do not accept it as such.

On the white screen, the light brightens the black colors and, contrary to what would be expected, also makes the whites appear darker and as if covered in a mist in the vicinity of these black colors. Here, again, our perception goes against the blind measurements of the devices.

Edward H. Adelson, in a work entitled "Lightness Perception and Lightness Illusions" demonstrates this perception (Image 7):

The star-shaped white space inside the square indicated by the upper arrow appears gray and cloudier than the one indicated by the lower arrow, although they have the same tone.

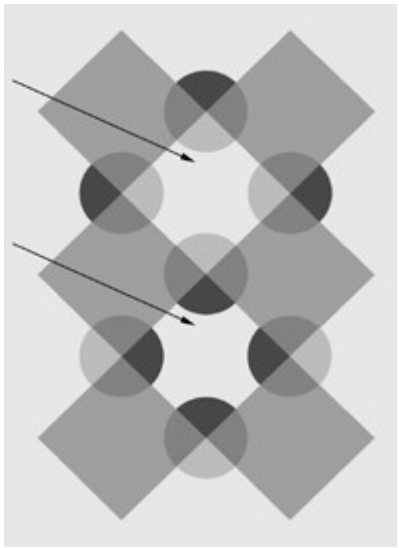

Image 7

So then, to have good contrast we should just use a plain gray screen, right?

No! If we use a screen that is simply gray, we will have blacker blacks, but the whites will also be getting less white as the screen becomes darker. At some point the loss in the whites of a normal gray screen becomes too much, and only a technical screen will solve the situation.

A darker technical screen gains contrast (blacker blacks) but loses less light when showing white colors than a gray screen. Some technical screens may even gain brightness in those whites, if they have gains higher than 1.

The brightness of the projector, the size of the desired image and the conditions of the room will dictate the choice of the appropriate screen.

In the image below, we see the example of a technical dark screen from Lusoscreen.

Although the screen has a negative gain, the conditions of the room are not the best and the projector is old and has a low light output (a Sanyo Z3000 from 2004), visually the final result is perceived as having an exceptional luminosity and contrast (Image 8).

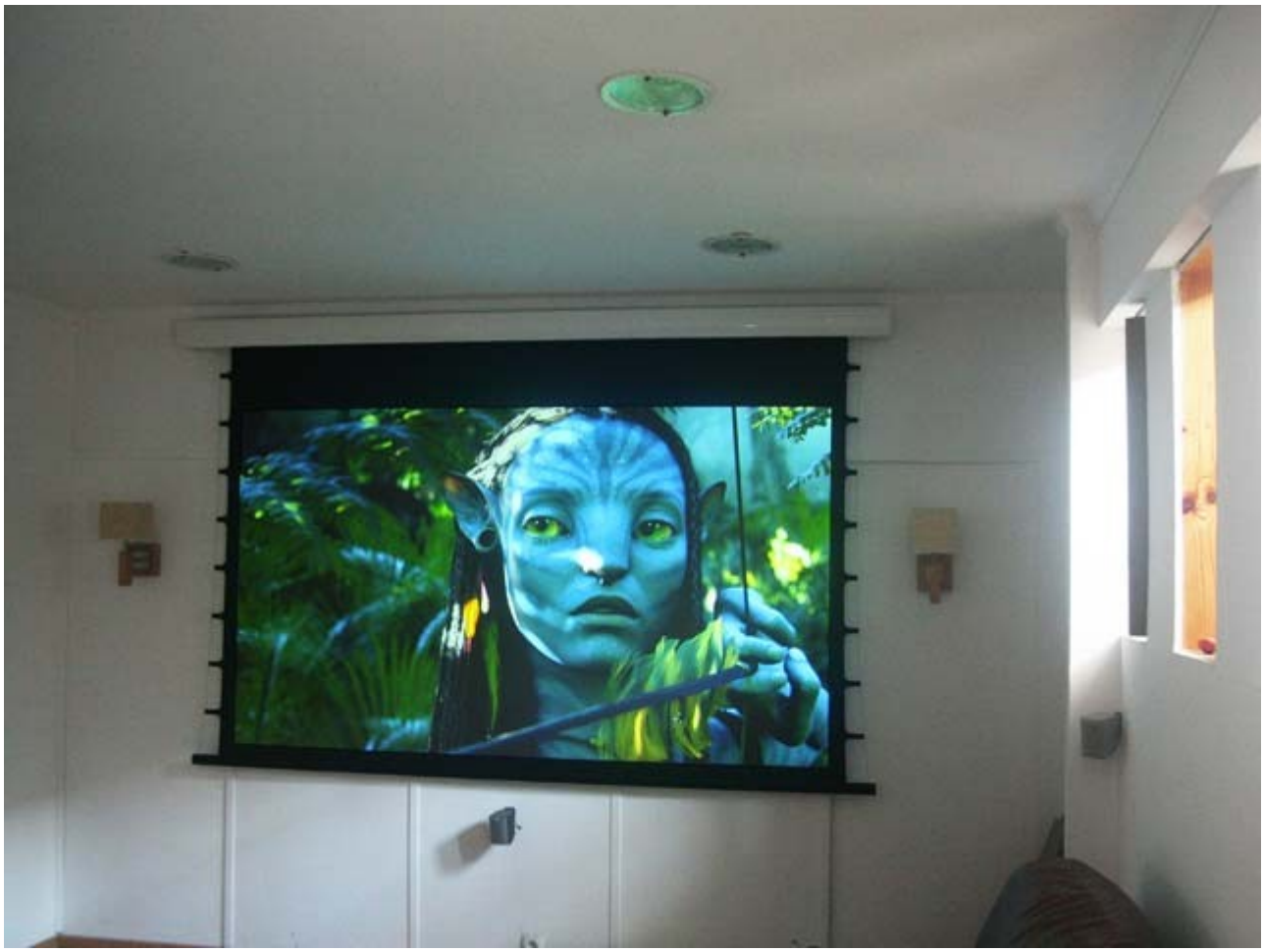

Image 8

Recapping what was said before, a screen in which the blacks aren’t deep will always give a "dull" image. Everything ends on the surface of the screen. As blacks become darker the effect of depth increases.

Returning to image 7 we can see that in the top vaguely-star-shaped space, the circles and the sloping rectangles all appear to be in the same plane, while in the one below the dark circles and white space appear to be behind the sloping rectangles giving an idea of greater depth.

It should be said, however, that today's video projectors tend to be ever brighter. In the impossibility of acquiring a technical screen, a screen that is simply gray (although it is inferior to a technical screen) can still bring some advantage over a plain white screen. Unfortunately the contrast obtained will always be proportional to the amount of light we lose, so the screen should be only slightly gray. A technical screen may, however, be much darker providing an incomparable level of contrast.

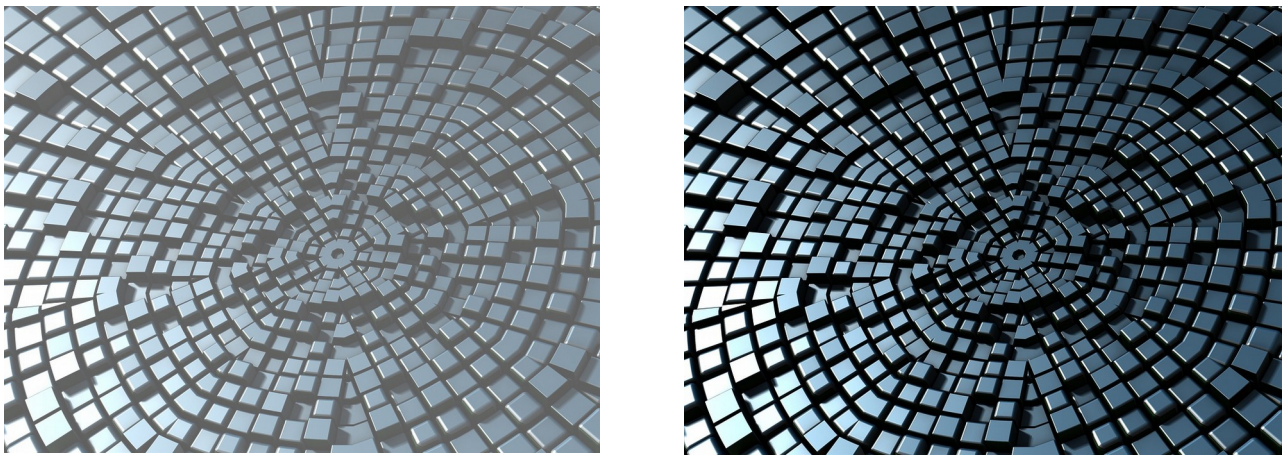

Image 9

Brightness

Let us now speak of brightness. The brightness of a projected image depends on the power of the projector and both the size and gain of the screen.

Let us think of the following: In a completely dark environment, even the light of a simple lamp with little light pointed at our eyes dazes us. However when we go to the beach we easily tolerate an illuminance of 100,000 lux or more from the Sun. This can give us an indication of how the size of the image and the distance we are from it can influence our perception of brightness.

Our grandparents used to say that watching television in the dark was harmful. What happened was that televisions were small at the time and their image occupied only a small percentage of our retina. When we moved our heads, there were receptors in our eyes that went from a lot of light to no light and this caused a dazing sensation, which means, in these circumstances, a television has too much light. There was even a well-known brand of TVs that went on to put a simple dark glass in front of the screens (reducing their light), won a reputation for high quality (despite the devices being equal) and sold them at exorbitant prices compared to others in the market.

On a beach under the Sun, our entire retina is illuminated, so there are no areas going from dark to light quickly and without time to adapt, which is why we are not dazed, despite the light being intense.

So the size of the screen and our distance to it, which causes a larger or smaller area of our retina to be occupied by its image, should be taken into account for the choice of brightness in a home theater instead of rigid numbers that uninformed “gurus” try to foist on us. The ambient light conditions of the room are also very important for choosing the brightness of the image. Nowadays people are beginning to understand that some ambient light is preferable to a room completely in the dark.

Our eyes have two types of receptor cells: cones and rods.

The cones are mostly used for color detection, and they work well in bright environments. The rods are more sensitive to light, and they work mostly in dark environments.

When we move from a very bright environment to a dark space, we become temporarily blinded and our eyes take between 4 to 6 minutes before they begin to adapt to the new conditions. It is after this time that the rods are activated. For about three more minutes the cones and rods work together, although the greater the darkness the less effective the cones will be, which is why we will tend to see everything in black and white.

From these initial minutes onward, the activity and sensitivity of the rods increases as they adapt to the darkness over the course of minutes and even hours.

This is a very simplified description, as many other factors influence this mechanism, such as the level of darkness, our age, etc.

All of these factors make our brain adapt to very different lighting conditions. This means that the choice of the brightness of our home theater is less rigid than usually indicated. So the preference of each person should also influence the choice of the brightness level of a movie theater, because while some people like very bright images others enjoy softer images.

Environment

As far as the environment of our installation is concerned, many people like to watch cinema in a completely dark environment, but more and more fans of watching movies in well-lit environments are showing up. Or at least of having some ambient light, in order to have an intermediate system between the cinema and a giant television. A light (for example a semi-open window) on one side of the room allows us to see the whole room and even perform some other activity simultaneously with the image projection.

Experiments with multiple volunteers conducted in the United States concluded that some brightness behind the screen led to a greater perceived contrast in the projected images. It especially made black colors be perceived as being darker, though it did not greatly affect the perception of whites.

If we think that an illumination behind the screen increases the total amount of light that reaches our eyes, causing our diaphragm to close more, it will be easy to understand the logic. Not only will it increase the feeling of more contrast, but the images will also appear sharper. Anyone who does photography knows that it is easier to focus with a closed diaphragm than with a very open one. And our eyes are far from the perfect craftsmanship of a camera lens.

No matter how big or how small of a percentage a projected image occupies in our retina, there is always an area of the retina that is left without light.

As was mentioned before, since it is impossible to have our head completely still, there are always receptor cells at the edges of the image that abruptly pass from receiving light from the image to receiving none at all. If the image is large enough then this does not cause a sensation of daze because our brain has enough information to continue to make us perceive it without problems. But over a long period of time, the effort of the receptor cells in the limits of the image, in the continuous attempt of readaptation, end up producing visual fatigue.

Which is why less and less people are opting for home theaters with dark walls and ceilings. The simple reflection of the light coming from the screen by the white walls and ceiling creates enough ambient light that make visualization for prolonged periods of time become less tiring. And with a proper screen, black colors won’t suffer from this luminosity.

The placement of indirect lights in places studied for this purpose will make the view even more restful and pleasant (Image 10).

Image 10

Angles

It would be great if the ambient light wouldn’t disturb the picture quality.

However, as the ambient light increases, the image on a white screen becomes increasingly dull until it is completely ruined.

This brings us to another feature of projection screens: the viewing angle. Only when using a technical screen it is possible to have reflection angles perfectly adapted to a particular room, while maintaining a good contrast in rooms with some light. The wider the angle of reflection however, the lower the immunity to lateral light sources and vice versa.

To say that a screen rejects ambient light (ALR) is an imperfect way of describing it. A screen that is said to be ALR does not reject any light, it only reflects it at different angles. A light that does not affect the projected image when placed, for example, on the side of the screen, will affect it more and more as we move it toward the projection axis. When next to the projector, it will act as if it was another projector, competing with the first and destroying the image contrast.

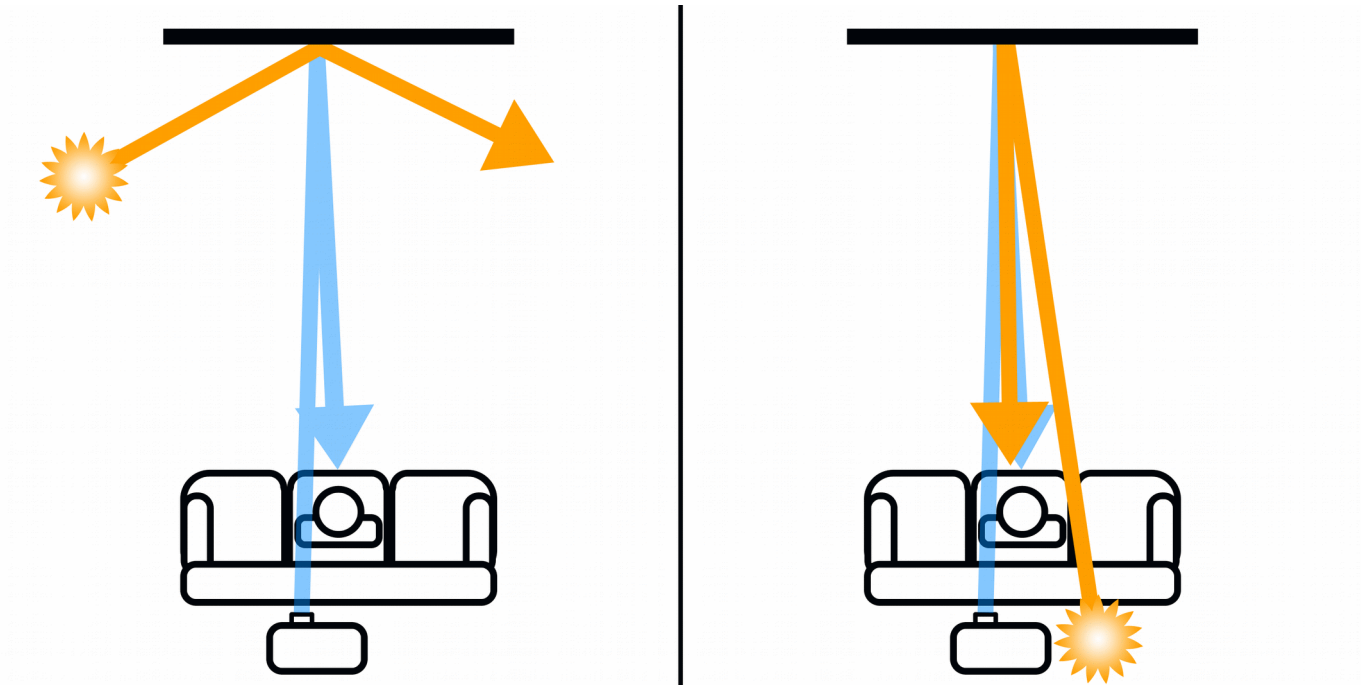

Image 11

The ideal reflection angle varies from room to room (and even with the use we give to that room). The distance from the projector to the screen and the number of regular users (only on the sofa or over the entire room) are also factors to consider when choosing the angle of reflection of the screen. The mistake of many people is to think that between

two screens with similar characteristics, the one with a wider angle is better, which is not true.

The narrower the reflection angle, the greater the gain and contrast that becomes possible using the same projector and vice versa.

In a room where only two or three users always sit in front of the screen on a sofa, there is no justification for "losing" light to the sides and / or to the ceiling and floor. And even in situations where there’s an excess of light, this excess can be converted into contrast by using a darker projection screen or choosing a brighter environment as it will not affect the quality of the image.

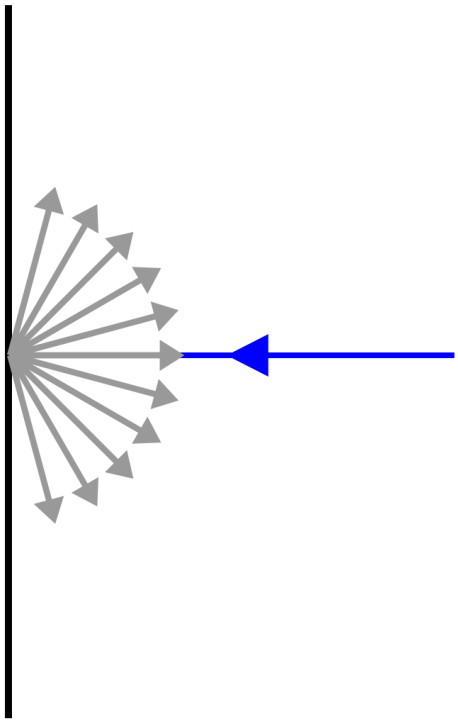

Image 12

When a beam of light reaches the surface of a normal white screen, 20 to 30% of that light is absorbed. The rest is diffused in all directions (Image 12). Regardless of where we are in the room, the image will always look the same to us.

Any light source that reaches that white screen (including the light from the image itself as it reflects off the walls) will also be absorbed in the same percentage, and the rest will diffuse in all directions by mixing with the image and destroying the contrast. That's the main reason why a white screen is always the worst solution.

If a surface is slightly reflective (and a good technical screen may even have different vertical and horizontal reflection angles), the light is diffused more or less, depending on the viewing angle (Image 13).

A screen that can send in our direction more light than a white screen (because it has a smaller viewing angle) allows us to darken it until the amount of light that arrives is at least equal to that of the white screen. This way we gain in contrast, while keeping the same brightness at the expense of the viewing angle. That is, much of the light we would waste on the ceiling, floor and sides is used more intelligently.

To put it another way: If you have 10 apples to distribute to 10 people, you can only give one apple to each one, but if you reduce the number of people to half, each one will receive twice the apples.

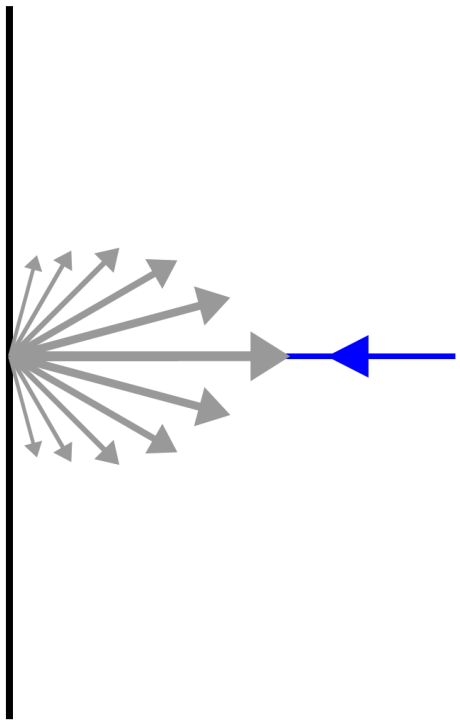

Image 13

But if the light that came from the projector when reflected on the screen comes back at a narrow angle to the sofa, the light coming from a source on the side, as it hits the screen, will also be reflected to the opposite side at a similar angle and doesn’t mix with the light that reaches our eyes (Image 11).

“Spot” Effect

A narrow angle of reflection on a screen has many advantages, but as this angle gets narrower, another phenomenon begins to appear: the so-called "spot" effect. While our brains can accept differences between the center of the image and the sides of up to 50% brightness, correcting this "spot" effect is still a good idea.

Image 14

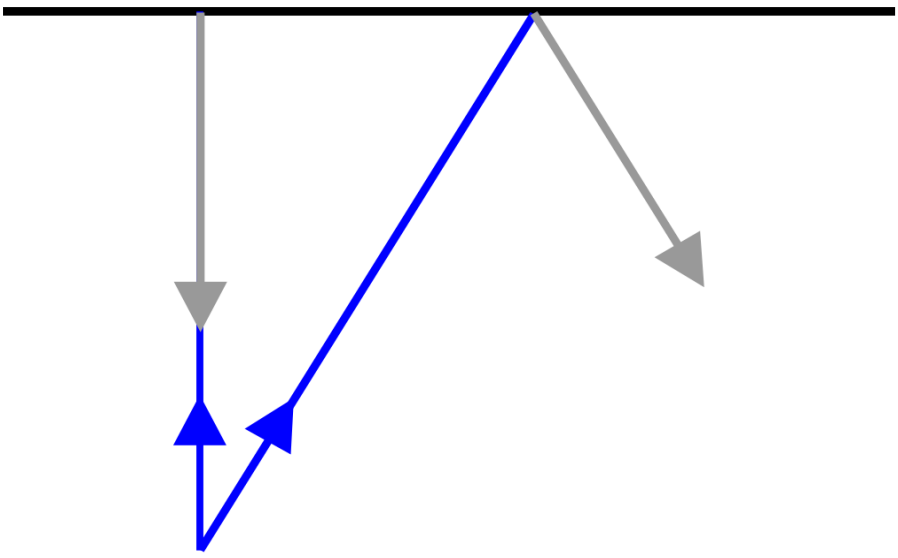

Image 15

In image 15, that represents half of a projection screen, we can see that the light reaching the screen on the right side is reflected farther to the right than the light reaching the screen in the center, which returns towards us. Because of this, the projected image will appear darker on the sides than in the center. This bright central area in the projected image is the so-called "spot".

The closer the projector is to the screen, the more sideways the light will hit on the sides of that screen, increasing the "spot" effect. That's why a narrow-angle flat screen benefits more from projectors placed beyond a minimum distance (which will be different from screen to screen).

A good way to balance angles, immunity to lateral light sources, spot effect, image uniformity, gain and contrast, is achieved exceptionally well using curved projection screens.

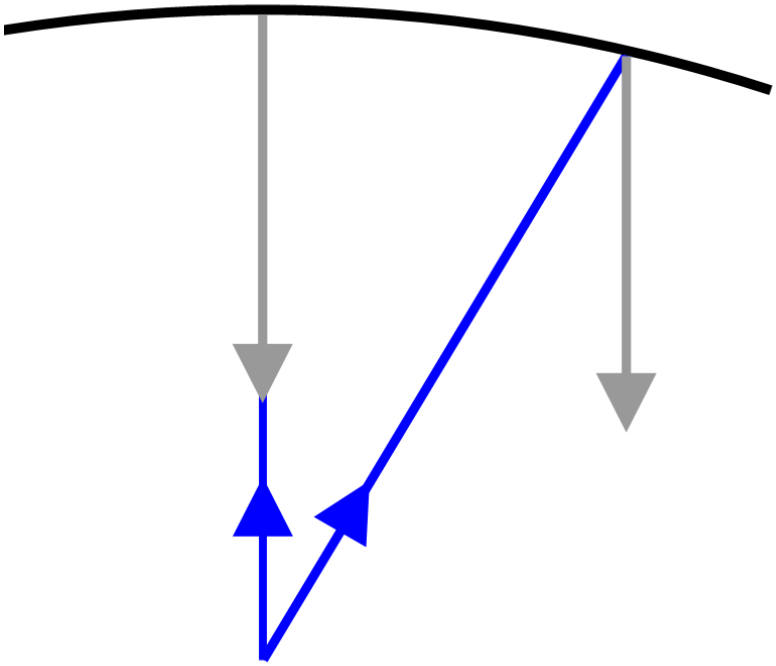

Image 16

When curving the surface, the light that would be reflected to the right (Image 15) is now redirected to us, thus eliminating the spot effect and obtaining an image with uniform brightness (Image 16).

Curved screens, with a convenient angle of reflection, allow such large immunity to the lateral light sources and such a concentration of light where it is needed (on the sofa) that they become the equivalent to a giant sized TV, for a percentage of the price of a much smaller one.

On image 17 we made the test in the worst possible conditions, with side windows open and 8 lights on the ceiling. Once again we used the old Sanyo Z3000 (15 years old at the time of this writing), and the capabilities of a good quality curved screen are readily apparent.

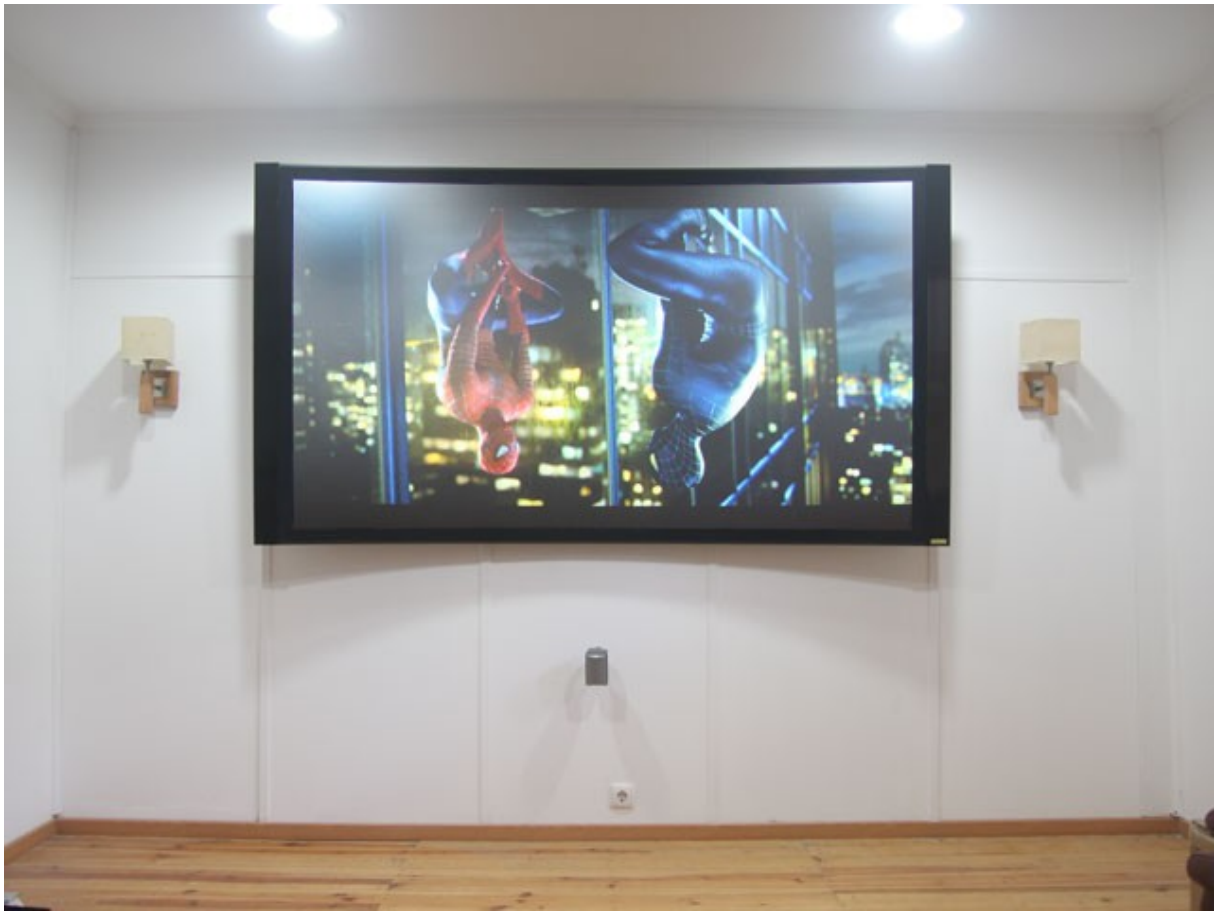

Image 17

Curved screens, however, require greater care with the placement of the projector than flat screens do.

No! It is not necessary to spend a fortune on anamorphic lenses to use a curved screen. If the projector is at a sufficient distance, and placed low (just above the heads of people sitting on the sofa), a black velvet border of a few centimeters all around the screen is enough to frame the projected image perfectly without the need for such lenses.

Screen height

As for the height at which a screen is hanged, again the rules make little sense.

In a commercial cinema we sit in a chair where we are more or less upright. At home things work differently and the custom is probably for us to recline on the couch. The screen should be higher the more reclined we sit. In the extreme case of reclination, one where we lay down completely, the correct position of the screen should be the ceiling.

So if we sit on our couch and check where our eyes naturally point to when we look at the wall, that's where the center of our screen should be.

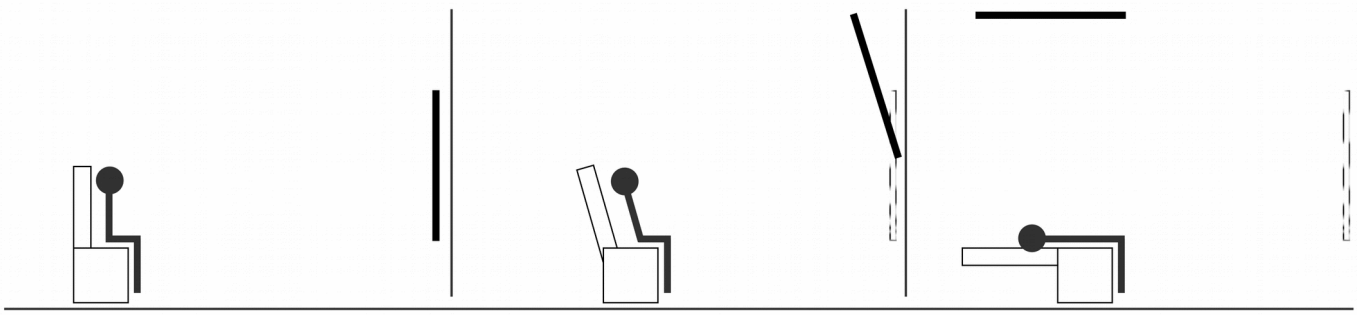

Image 18

Mounting the screens

In addition to the type of screen, the way it is used (more or less stretched) also interferes more or less in the result.

Many people purchase rolling screens for use with short throw projectors. The result is usually a tremendous disappointment and it’s easy to understand why.

Try the following: Take a normal white A4 sheet. In a dimly lit space, place the sheet on a table. Next, with a flashlight (the one in your smartphone will do) light the sheet from the top. The result will be similar to image 19.

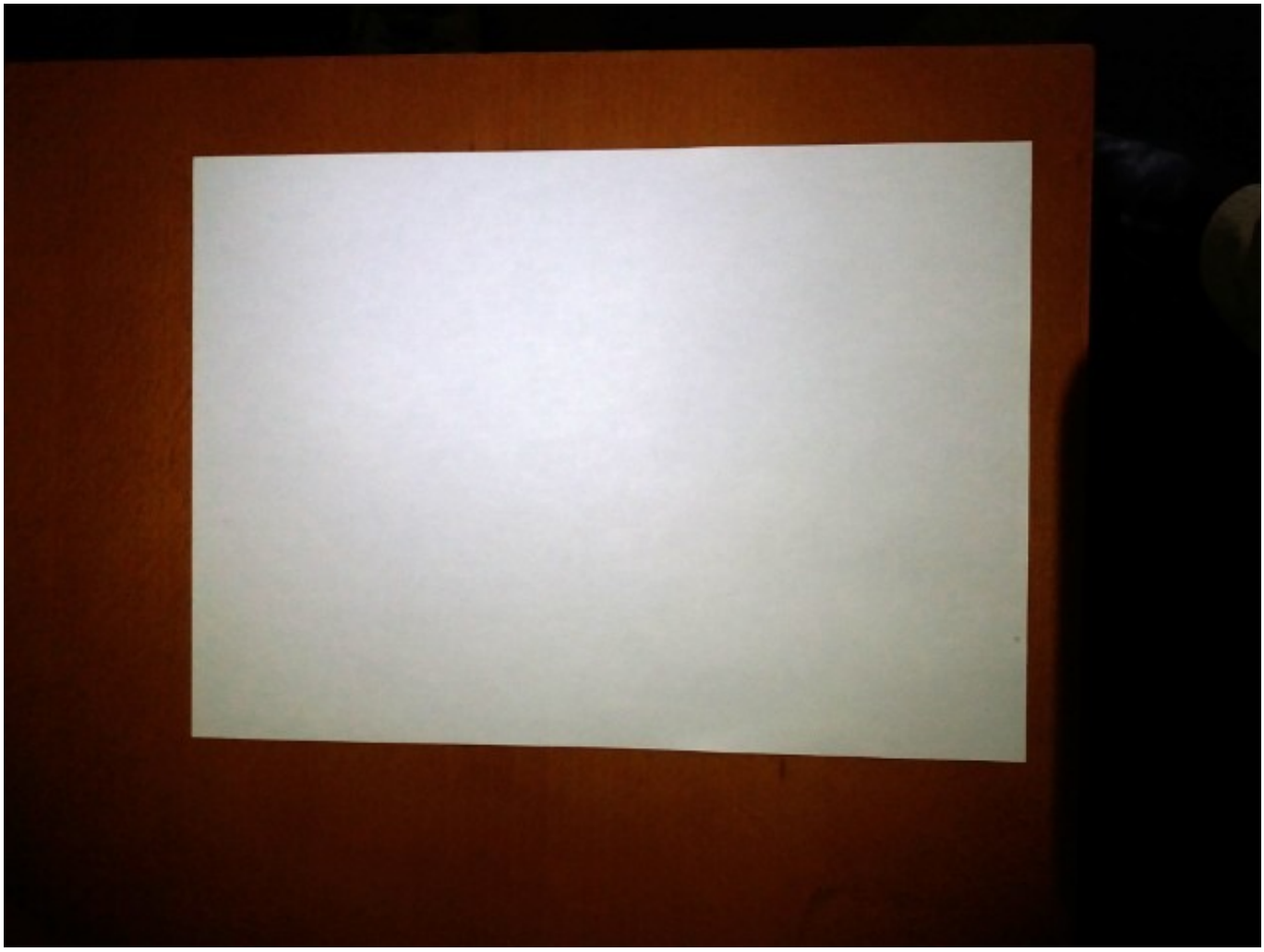

Image 19

The sheet appears smooth and with a fairly flat surface.

If we then illuminate it with an oblique angle, we will see that, surprisingly, the sheet does not look as flat as before (Image 20).

Image 20

What happens is that the small protrusions on the surface of the sheet will be illuminated laterally while causing shadows in the adjacent depressions, creating a great contrast of light and dark zones that give the illusion of a sheet that is much more deformed than it really is.

This is why screens for short-distance projectors (which project light to the screen obliquely) must be fixed and well stretched in order to achieve a straight surface.

As for normal lens projectors, a white screen, because it diffuses light in all directions, supports significantly larger ripples compared to screens with lower viewing angles. The smaller the angle of reflection, the more stretched the surface of a screen should be (we are not talking about the micro-irregularities of the surface itself, but the ripples created from a more or less stretched screen). Thus, the best screens, especially those of technical characteristics, are usually rigid or, if they are to be rolled, should be tensioned to minimize ripples.

Overall conclusion

There are many factors to take into account when choosing the screen for our home theater system. The right choice is essential for a good end result.

If someone wants to sell you a screen without wanting to know at least how far is the distance from the projector to the screen, and from the couch to the screen, to know a little about your tastes in terms of image, to know the position of light sources, etc. this person will be a salesman only interested in selling what he has, with little concern with serving you well.

As with everything, in order to make a good choice, the help of knowledgeable people is fundamental.

Despite being somewhat long, this text is still only a slight approach to this topic. A lot of people claim they do not like projected images, but this is only because they do not realize the importance of the projection screen in a home theater system and/or use the wrong screen for their situation.

If we compare the projector to a car, the screen is the road, and although without a projector there is no image, for the final result the screen is as important or even more important than the projector. *Even a Ferrari going through hills and valleys loses against a bicycle riding on the highway*.

Lastly, the old adage of "you get what you pay for" applies to all products and, as such, also to projection screens. We usually get results based on what we pay for. A screen of a single layer interacting with light is very different from another having four, five or more optical layers. They have different degrees of complexity and, of course, their prices are also different. Sometimes it is preferable to take more time, to analyze things more carefully, informing yourself as much as possible, so that you can purchase the definitive screen at the first try. A projector has a lifespan and gets outdated at regular intervals. A good projection screen, on the other hand, can be an acquisition for a lifetime.