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Thesis

"Screening and testing during the COVID-19 pandemic: An STS perspective"

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Περίληψη

Η παρούσα εργασία αποτελεί μια STS προσέγγιση σχετικά με τους διαγνωστικούς ελέγχους κατά τη διάρκεια της πανδημίας Covid-19. Αρχικά, πραγματοποιείται μια εισαγωγή στο θέμα και εξετάζεται η τρέχουσα κατάσταση σχετικά με τις πολιτικές διαγνωστικών ελέγχων παγκοσμίως. Ακολουθεί βιβλιογραφική ανασκόπηση των όρων "testing" και "screening", καθώς και ανάλυση των διαφορών μεταξύ των δύο όρων. Αναλύονται οι κύριες τεχνικές "testing" και "screening" που χρησιμοποιήθηκαν κατά τη διάρκεια της πανδημίας.

Το κύριο μέρος της εργασίας περιλαμβάνει μια STS ανάλυση βασισμένη σε τεχνικά κείμενα που σχετίζονται με μεθόδους διαγνωστικών ελέγχων. Κάθε μέθοδος μελετάται ξεχωριστά, ενώ, σε ορισμένες περιπτώσεις, εξετάζονται συγκεκριμένες συσκευές που διατίθενται στο εμπόριο. Αυτή η ανάλυση στοχεύει να δείξει ότι οι διαγνωστικές μέθοδοι που χρησιμοποιούνται κατά τη διάρκεια της πανδημίας δεν είναι πολιτικά ουδέτερες.

Η εργασία καταλήγει στην αναγκαιότητα ύπαρξης μιας STS προσέγγισης του ζητήματος για δύο λόγους. Πρώτον, κάθε μέθοδος "testing" και "screening"– καθώς και οι πολιτικές που σχετίζονται με αυτές– φαίνεται να έχουν σημαντικό κοινωνικό αντίκτυπο που πρέπει να εξεταστεί περεταίρω. Επιπλέον, μια τέτοια προσέγγιση φαίνεται να οδηγεί σε καλύτερη κατανόηση και βελτιστοποίηση των εν λόγω μεθόδων.

Λέξεις κλειδιά: Κορονοϊός, Διαγνωστικές μέθοδοι, Τεστ αντιγόνου, Τεστ αντισωμάτων

Abstract

This thesis puts forward an STS approach to testing and screening during the Covid-19 pandemic. Initially, this text provides an introduction to the subject and examines the current situation regarding testing policies worldwide. What follows is a bibliographic review of testing and screening, as well as an analysis and demarcation of the differences between the two terms. The main testing and screening techniques utilized during the pandemic are subsequently dissected.

The main part of the thesis comprises an STS analysis based on technical texts relating to testing and screening methods. Each method is studied separately, while, in some cases, specific commercially available devices are being examined. This analysis aims to show that the testing and screening methods employed during the pandemic are not politically neutral.

In the conclusion, it is suggested that approaching this issue from an STS perspective is necessary for two reasons. Firstly, each testing or screening method –as well as the policies that are associated with them– seem to have an important social impact that needs to be scrutinized. Furthermore, such an approach seemingly leads to a better understanding and optimization of the methods in question.

Key Words: Covid-19, Testing, Screening, RT-PCR, Antigen test, Antibody test

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Aknowledgements

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1. Introduction

1.1 The Covid-19 pandemic

Human susceptibility to certain viruses has been well-documented, but their effect on the general population can vary wildly. While some of them are relatively benign, others might lead to deadly pandemics that precipitate extensive illness and a devastating loss of life. The 2020 pandemic caused by the spread of the SARS-CoV-2 virus has, to date, led to millions of reported deaths and a major disruption of global commerce, education and societal conduct in general. Transmission of the virus is widely understood to occur via respiratory droplets as well as from contact with contaminated surfaces. Testing and screening of the population seems to be a key measure in global society's struggle against the spread of the virus. Therefore, as illustrated below (Figure 1), states worldwide provide their citizens with a remarkable number of tests. However, despite the development of viable tests for determining the presence of the virus in a human host, the different ways in which they work are not clear to the lay public: i.e., the various testing methods are not as openly analyzed and discussed as they should. On the contrary, they are exclusively deliberated among technocratic groups that include a limited number of scientists. The latter are considered to be the only people suitable to decide which testing policy will be followed in order to combat the Covid-19 pandemic. Arguably, this is rather intriguing, as it is politicians –and not scientists– who usually have the final say on policy.

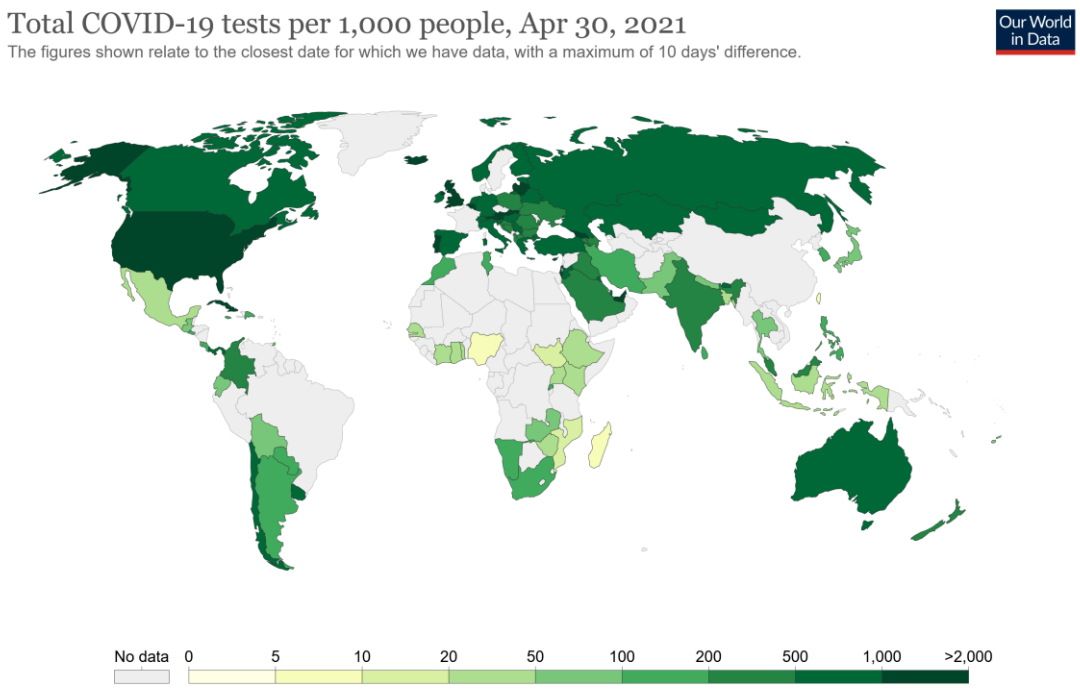

Figure 1. Tests per country worldwide.(Our World in Data, 2021)

1.2 COVID-19 Testing Policies

In this section we will examine the various policies pursued by different states worldwide with regard to testing during the Covid-19 pandemic.

As illustrated in the next figure (Figure 2), states all over the world adopted a number of different testing policies regarding the Covid-19 pandemic at a certain point of 2021's second quarter. Except for Tajikistan (which, at that time, seems like it had no testing policy whatsoever), all other states that provided sufficient data appear to follow one of three different testing strategies. According to the first strategy, the state provides coronavirus tests only to people that meet specific criteria (e.g., concerning their age or health condition) in addition to exhibiting coronavirus symptoms. In the second strategy, the state provides tests to everyone who exhibits coronavirus symptoms. In the last strategy, the state provides tests to everyone.

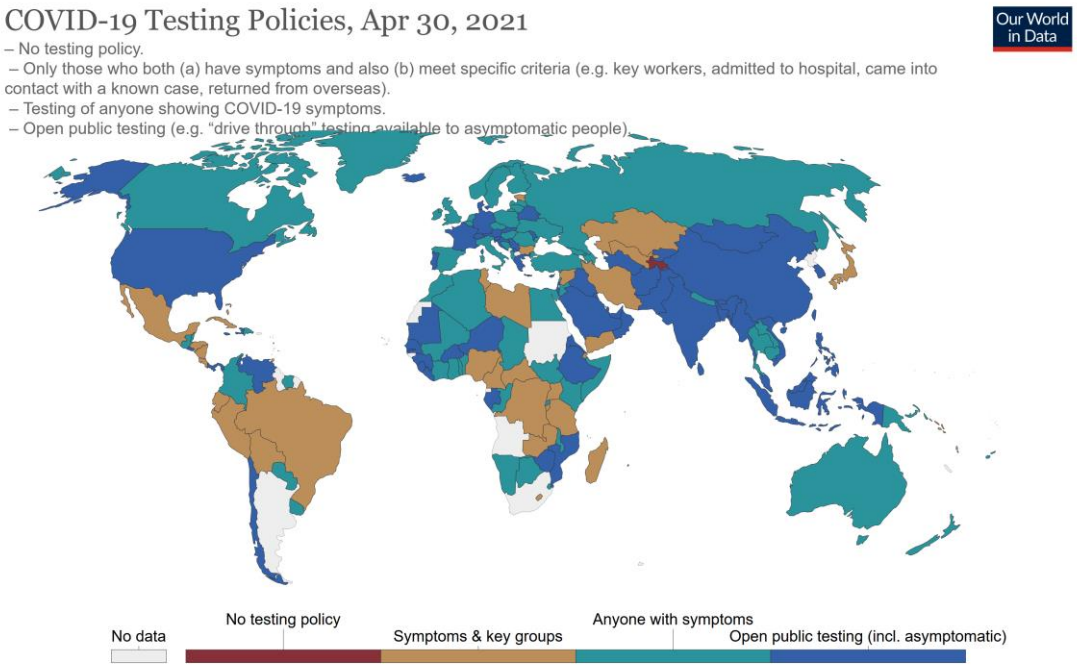

Figure 2. Testing strategy per country.(Our World in Data, 2021)

A comprehensive examination of this figure reveals that a state's preference for one of these three strategies was not necessarily defined by its location –as all major geographic regions include at least one state that follows each of these strategies– or, even, by its economic well-being. This means that the choice of a certain strategy on testing is a mostly political undertaking. In fact, according to an analysis carried out by Shaw et al., the model of governance followed by each country had an important impact on how the Covid-19 pandemic has spread throughout its territory and how it was dealt with (Shaw et al., 2020). In addition, according to their research, various innovative technologies were used and, seemingly, the technologies developed and employed had a strong bearing on each country's governance model.

Further researching how a state chooses to pursue some of these policies can produce interesting results. More specifically, identifying the criteria on the basis of which a selection is made appears to be quite merited. However, this research ought to be rather cautious, as it should not be claimed that, at first, some politically neutral tests are constructed by resorting to purely technical criteria and, having achieved that, politicians are asked to choose a testing strategy. Moreover, it would be warranted to compare the testing policies during the initial stage of the pandemic –when not only there was a shortage of tests but, also, the existing tests were of low reliability– with

the policies implemented during the later stages of the pandemic, when there were plenty of much more reliable tests.

1.3 Research objectives

As already seen, testing can be crucial in dealing with the pandemic more effectively. Admittedly, by now there are several efficient testing methods that make use of various techniques and new ones are constantly being developed. Therefore, it is important to explore the effects of each method. On this thesis, I will argue that different testing methods are not just different ways of doing the same thing, whose selection depends upon the circumstances. On the contrary, I will argue that every testing method corresponds to a specific policy. Therefore, exactly which testing techniques will be developed and how they will be implemented is a policy decision that is determined even before a method is developed. Finally, I will argue that, even if the tests with the best specifications –from an engineering perspective– are designed and developed, society's profit from their use will be much smaller than if the logic behind each one of them (and the policy they implicate) are clearly demonstrated.

My approach will be mainly based on a theoretical perspective closely linked to STS – namely Langdon Winner's approach on artifacts and their politics (Winner, 1980). Winner examines, as the title of this article indicates, whether technological artifacts correspond to specific policies. In contrast to the prevailing ideology (which claims that technological products are neutral and that the burden of "proper use" falls on those who use them), Winner shows that objects formulate a specific policy on their own. This aspect of theirs becomes apparent in the way they have been designed and manufactured. Instead of surveying technological artifacts in general (as Winner does), this approach will be applied to a very particular subcategory of them: coronavirus tests.

1.4 Thesis outline and methodology

The present thesis is structured in six chapters. The first three chapters basically provide a literature review concerning the concepts that are considered necessary for the analysis expounded in the second part and, also, for the formulation of this thesis's conclusions. In the second part, since the applicable theorizations have been

demonstrated, the pertinent analysis is carried out and specific questions (which had already been set forth in the first part and the literature review) are addressed.

Specifically, the first chapter serves as an introduction to the topic of the thesis and to its objectives. The second chapter discusses the theoretical framework and the methodology followed, mainly by analyzing the concepts of testing and screening – both from a technical and a sociological point of view. The third chapter presents the different methods and techniques developed (in the past but, also, currently) for the purpose of virus detection. In addition to the technical analysis, there will be a discussion about which of these methods seem ideal for testing and which methods seem ideal for screening. After providing some crucial information for this thesis's research, in the fourth chapter I gather the data provided so far and attempt to transform the research objectives stated in the introduction to research questions.

In order for the questions that were put forward in the first chapters to be answered, a qualitative analysis will be conducted, based on a textual analysis of published documents. The primary sources include 23 scientific papers (which were gathered by searching in engineering and medical journals and implementing a snowball method), four articles retrieved from newspapers and certain official Covid-19 pandemic statistics. As for the secondary literature, it consists of STS and social science perspectives on testing and screening (with a total of nine scientific papers). All main categories of existing coronavirus tests will be studied separately in this thesis's fourth chapter. In more detail, there will be a section dedicated to an analysis of the RT-PCR method, one on antigen tests and one on antibody tests. First, each testing method will be studied from a technical point of view. Although, to some extent, this might have been done in the first part of the thesis, it will nonetheless be enhanced by breaking down additional technical texts. The STS analysis of each method will be based on such technical texts, from which I will try to draw sociological conclusions and investigate whether these testing methods can be matched to specific policies. Moreover, in these technical texts I will try to identify what has been described in the approaches/perspectives that were analyzed in the second section of the thesis, regarding testing, screening and their social effects. Therefore, after the STS analysis, the basic objectives of the thesis will have been enriched, redefined and fulfilled. In

the last chapter, some key conclusions will be underlined and some directions for future research in this field will be set out.

2. Testing and Screening

This section serves as an introduction to medical testing and screening. I examine these practices from a sociological perspective, trying to identify any similarities and raise questions on testing and screening during the Covid-19 pandemic. There will be an attempt to transform the research objectives into research questions. The following introduction to testing is based on "Put to the test: For a new sociology of testing" by Noortje Marres and David Stark (Marres and Stark, 2020), as well as "What the pregnancy test is testing" by Joan H. Robinson (Robinson, 2020). The introduction to screening is based on "The sociology of medical screening: past, present and future" by Natalie Armstrong and Helen Eborall (Armstrong and Eborall, 2012).

2.1 Testing

In the field of medicine and biomedicine, a test is a scientific method to provide a probability for a certain result. It can be quantitative, semi-quantitative or qualitative, indicating that the answer is a simple yes or no, like the pregnancy test. However, when inspected from a sociological point of view, a test can be much more than a scientific probability.

N. Marres and D. Stark argue that testing modifies the social environment directly and on purpose. They believe that we are past the time when tests came into society out of the laboratory. Instead, in our times, testing can applicable to every aspect of daily life and strongly affect it, creating an all-encompassing test environment. Moreover, the authors assert that a test, its purpose, its effects and even its results are significantly different when the test is done in the laboratory or in a limited social environment, compared to when it is performed uncontrollably in society. Therefore, since testing modifies the social environment but we do not know exactly how, we need to study this issue more comprehensively (Marres and Stark, 2020).

Take for example one of the most famous and commonly used tests, the pregnancy test mentioned above. Most people would say it is just a method to find out whether a

woman is pregnant. Joan H. Robinson, though, argues that the pregnancy test is actually testing much more. It tests your social role – for instance, whether you are a "bad daughter" staying pregnant when you were not supposed to. It tests your relationship – for instance, whether you trusted your companion to be with you the moment you did the test or not. It might also tests your responsibility – which is, probably, the most applicable aspect to the present study. In the case of the pregnancy test, it tests your responsibility, as you have to decide whom you will inform if you are pregnant or not or what you will do after learning the results. This might even be extended to whether you are having regular check-ups in order to be able to control your sexual life (Robinson, 2020). In the course of this thesis it will become apparent that testing during the Covid-19 pandemic also tests your responsibility in more ways than one.

2.2 Screening

Medical screening refers to a strategy utilized in order to prevent something – e.g.: a virus pandemic. Screening is applied to an individual or a large number of people (regardless of whether they have symptoms or not), so as to detect a problem at an early stage. Here, it is important to remember that early detection can make a problem easier to treat. From a medical perspective, the main difference between screening and testing is that the former targets asymptomatic people whereas the latter targets people with symptoms. Aside from that, screening is also cheaper. Testing has better chances to prove a person sick and is part of the treatment, whereas screening functions as a preventive strategy. Critically, screening is designed in a way that makes it easily acceptable by people. On the other hand, testing is meant to be more helpful to the patient, as it is mainly centered on a precise result. This means that screening entails an important chance of a false diagnosis (Ruf et al., 2017). All these observations stem from a medical perspective but, as with testing, there is also a sociological one.

According to Armstrong and Eborall, except from a medical intervention, screening is also a social intervention and, thus, raises important social questions (Armstrong and Eborall, 2012). Their claim relates to the fact that screening gives rise to a huge market and, sometimes, the data about it are not clearly presented to the general public in order to maximize the gains. Even though, as mentioned above, screening tests do not have the greatest sensitivity and specificity, that fact is often

underestimated, leading to a mistaken use of screening to create a false certainty about being in danger or not.

Screening might not be so expensive when applied to an individual, but it is expensive when applied to a population. For this reason, screening is usually suggested for specific population groups that are considered to be in serious danger from a specific issue. This fact is mainly derived from on economic and not a medical perspective and, again, it can lead to misuse. For example, limiting screening to a specific population group seems rational if you think that everyone could be in danger from a virus, but it is these groups that statistically are more in danger – without this meaning that an individual belonging to such a group is in danger for sure or that someone who does not belong to this group is not. In other words, limiting screening to specific population groups is rational, when it is clear that these groups are only chosen on a statistical basis and not due to certainty. However, potential misuse is a result of not fully disclosing to the public why you limit the screening to these particular groups. That can happen because of financial interests or, even, due to a shortage of information and it can lead some people to form this opinion: "I certainly can [or cannot] get sick from this factor because of my age or because of my gender". Even stereotypes can be created – e.g., believing that the people of a specific ethnic group or gender bear an illness.

From a psychological perspective, mainly two things need to be noted. Firstly, a screening test can create anxiety – especially when it indicates someone is positive and, thus, that they need to undergo further examination (Orbell et al., 2008). In addition to that, screening can generate false reassurance when someone takes a negative result at face value, despite it being the product of a low sensitivity and specificity test (Pettrigrew et al., 2000).

Another important thing about screening is its attendance. As already stated, screening is applied to a large number of asymptomatic people in order to find a few of them that are in immediate danger from a specific factor. Thus, if a screening is attended by a large number of people from a certain group, the chances to limit the danger for this group are increased. However, attendance is not such a simple issue, as it is affected by factors like whether you feel comfortable with your body being monitored, if you feel responsible as a citizen, if you are well informed, if you want to

participate knowing the high chances of a false diagnosis and other similar reasons – which, according to Armstrong and Eborall, need to be further analyzed by the sociology of screening (Armstrong and Eborall, 2012).

Finally, Armstrong and Eborall emphasize the need to go beyond the experiences of individuals that are either possible patients or health professionals and examine the infrastructure of screening – i.e., how the new screening technologies are designed and implemented and what is their impact (Armstrong and Eborall, 2012).

2.3 Testing in Pandemic Times

It has already been detailed how Marres and Stark believe that testing modifies the social environment, as we live in the age of testing. Especially in these times of pandemic, David Stark argues that the already important role of testing in society is greatly enhanced, as testing occurs in almost every news piece or conversation. To examine the social effects of testing, he introduces three terms: representation, selection and accountability (Stark, 2020). Representation refers to the degree that a test's results correspond to reality. Each test represents something – for example, a school test represents a student's ability in a lesson. Of course, this correlation is not linear and, consequently, the representation of each test is something that needs to be evaluated. Especially regarding the Covid-19 pandemic, tests represent many things that have both a sociological and a political aspect – like how well you do in the fight against the virus (by finding where you are in the curve) or how well your country, government or, even, your city does. Selection refers to the utilization of the data obtained from the test, both on an individual level (such as on the issue of who is sick or who is immune), as well as on a group level (such as ascertaining what is the spread of the virus, in which areas it is greater etc.). Finally, accountability is a term that is difficult to define, as, in order to do this, we need to clarify what it refers to – e.g.: deaths, lives saved or the economy? Depending on the criterion formulated each time, accountability might affect the social and political landscape. For example, it can affect the way a government deals with the pandemic or even social relations.

2.4 Discussion

Reading and analyzing these articles can help us more specifically focus our research about Covid-19 testing and screening on certain issues. First of all, we will need to

examine if the diagnostic technologies manufactured for the pandemic are designed for testing, screening or both. Now that it is clear what testing and screening are, we can look back at Figure 2 in the introductory chapter. From that figure we can now realize that, out of the 3 different testing strategies states have followed, only one includes screening. That is the last one, in which testing is provided to everyone, as it is the only strategy that provides tests to asymptomatic people. Furthermore, we will need to examine exactly how diagnostic technologies are designed, how they intend to include individuals and what is their impact to society, as well as to the life of individuals. Until today, there are still many things about the virus that are unclear both to the scientists and, especially, to society – for instance, which test should be used in each occasion or how to decide that an individual is positive to the virus (whether symptomatic or asymptomatic). Even though these things are not clear, what Ilana Löwy describes is quite telling: data about the virus and the tests continue to be presented by the media and in public discourse as a simple 'scientific fact'. It goes without saying that these data are used to shape public policies (Löwy, 2020).

3. Testing and Screening Techniques

3.1 Technical Specifications

This section presents a short introduction to the technical specifications of testing techniques. Its aim is to familiarize the reader with some of the terms used by engineers for evaluation. Of course, as it should already be obvious but will be understood more substantively in the second part of the thesis, each specification has a different meaning, depending on whether we intend to use a technique for testing or screening.

The first term that needs to be dissected is sensitivity. Sensitivity shows how reliable a technique is at detecting what it targets – in our case, SARS-CoV-2. In short, sensitivity signifies how the output of the test changes as we alter the quantity of the viral load in the test's input. Sensitivity is different from efficiency, which refers to what percentage of test results corresponds to reality, regarding whether someone is ill or not (Mina et al., 2020). Then there is the limit of detection (LOD). LOD denotes the smaller viral quantity that a testing device can recognize – i.e., what is the minimum viral load in the sample provided in the test's input, in order for it to turn

positive. Something also important is the selectivity of the device – i.e., whether the device is only sensitive to the specific virus or if it could misinterpret another biological quantity existing in the sample (swabs or blood) as the virus. Moreover, emphasis is given to the simplicity of the technique, which may refer to whether the presence of a professional is necessary for it to function correctly and, also, to how comfortable it is for the patient. Last but not least, the time period required to provide the results as well as the technique's cost are further important issues.

3.2 State of the art for SARS-CoV-2 testing

In this section we will discuss the standard method used for testing in the Covid-19 pandemic: the Real-Time Polymerase Chain Reaction (RT-PCR). The method will be reviewed both from a technical and a sociological point of view.

The standard method used worldwide to detect the Sars-Cov-2 virus is the Real-Time PCR. This method is highly specific because it detects a portion of the virus's genome. To perform this analysis multiple steps are required, along with several reagents, enzymes and specific machines able to amplify the cDNA (complementary DNA) and, at the same time, measure fluorescent chemicals. From the time the samples reach the analysis center, at least five to six hours are required to obtain results.

The first step is the isolation of the virus genome. Sars-CoV-2 is an RNA-virus, which means that its genome is a single strand of RNA molecule. This adds extra steps to the protocol because the real-time PCR test only works with DNA molecules. The isolation of RNA requires the use of specific reagents, which are mixed with the patient's biological sample. After a varying period (in the order of minutes), the RNA is isolated and ready for the second step.

The second step is the reverse transcription of RNA into cDNA. To perform this reaction, commercial kits are available. These kits contain all the necessary reagents to transform RNA into cDNA.

After the reverse transcription, it is estimated that the number of generated cDNA molecules are the same as the RNA molecules, which represent the amount of virus in the sample. The cDNA is then subjected to amplification via real-time PCR because, even though it is known that some sort of genetic material is present in the patient's

sample, it is not possible to identify it. In other words, it is not possible to know whether or not it belongs to Sar-cov-2, to other pathogens or, even, to the patient. The identification only becomes possible after verifying the presence of a specific cDNA sequence that belongs to Sars-Cov-2.

To perform real-time PCR a number of reagents are necessary, which are usually included in commercial kits. Among them, the most important are primers, the enzyme named Taq polymerase and a fluorophore that binds DNA. Primers are two short DNA oligonucleotides whose sequence perfectly matches with the SARS-CoV-2 genome. The two primers are the "tools" that guarantee the presence of SARS-CoV-2 virus in the sample. Indeed, due to statistics and probability, a DNA sequence of roughly 20 nucleotides is unique in nature and belongs only to one species. In the case of real-time PCR two 20-nucleotides primers are used. Therefore, the genetic identification has a margin of error that is almost zero. The other main reagent is the Taq polymerase, which is an enzyme able to synthesize a new DNA strand starting from a cDNA template (the one generated from RNA's virus). At each PCR cycle, the initial cDNA molecules are exponentially amplified. Therefore, after 25-35 amplification cycles, in the reaction tube there will be enough DNA molecules to generate sufficient fluorescent light to be detected by a CCD camera integrated in real-time PCR machine. Once fluorescent light is detected, it becomes possible to state that in the reaction tube a DNA sequence that belongs to SARS-CoV-2 is present and, thus, classify the sample as positive.

The real-time PCR also offers the possibility to quantify the amount (viral load) of the virus present in the patient's body fluid. Indeed, as mentioned earlier, in the PCR reaction Taq polymerase needs a cDNA template in order to synthesize new DNA. If the amount of the initial cDNA template is high, less amplification cycles will be necessary to reach the detection limit. Vice versa, when the amount of initial cDNA template is very low, more amplification cycles will be necessary in order to reach the detection limit (Figure 3). By using an analytical DNA template with a known amount of DNA, a quantification standard curve is constructed by plotting the number of cycles necessary to detect fluorescence versus the DNA amount. Once the standard curve is constructed, in order to know the amount of DNA (and, indirectly, the viral load) it will be sufficient to record the first cycles at which a signal is detected and,

then, extract the corresponding DNA amount. Modern real-time PCR machines perform this quantification automatically. Therefore, after the reaction, the machine provides both positivity and viral load(Bachman, 2013).

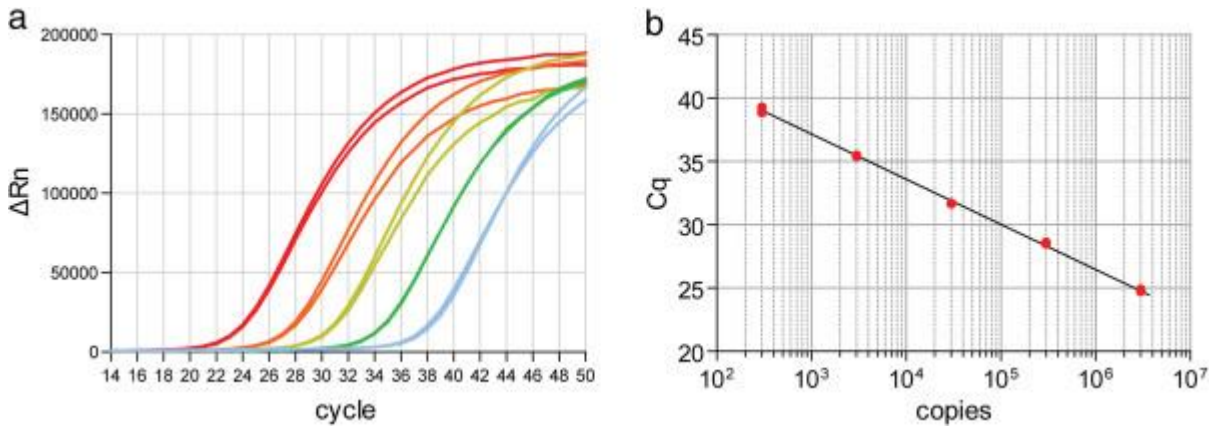

Figure 3. Example of real-time PCR results. A. amplification curves of different DNA templates. B Standard curve generated by plotting the cycle number (CT) versus number of DNA template (copies). High number of DNA molecules (copies) are detected with a smaller number of amplification cycles, low DNA copies need more amplification cycles to be detected. ΔRn indicates arbitrary fluorescent units(Roberts et al., 2014).

This detailed analysis of the function of RT-PCR has been demonstrated in order to draw some conclusions about its use. First of all, just from the number of materials that this method involves, it is obvious we are talking about an expensive method. Also, we are talking about a time-consuming method that obviously requires specialized personnel and specific areas of appropriate specifications to perform it. On the other hand, we are talking about a method that shows great accuracy and reliability if performed by experienced staff. If not, there is a high chance of indicating that healthy people are sick.

3.3 State of the art for SARS-CoV-2 screening

As shown in the previous section, RT-PCR is more ideal for testing. In this section we will examine techniques that seem most ideal for screening during the Covid-19 pandemic. Their function will be analyzed in order to reach some conclusion about their social impact and implementations.

The main categories of tests that seem to be ideal for coronavirus screening are two: antibody tests and antigen tests. Even though there are various types of antigen and antibody tests, in this thesis we will mainly examine the rapid ones, as they are the ones used during the Covid-19 pandemic.

3.3.1 Antibody tests

Antibody tests are not used to determine whether someone is infected by the virus at the time of testing, but, generally, to find out whether someone was infected by the virus in the past and has developed antibodies. More specifically, it has three possible uses. Someone can use it to determine whether they had been infected by the virus but were asymptomatic. In case they exhibited symptoms but were not sure if this was due to the virus, they can use it to learn whether they have developed antibodies to it (which would also imply that, at some point, they had been infected). It can also be used by someone who has been vaccinated or knows they had been infected, so that they ascertain if they still have antibodies. As for their manufacturing and use, antibody tests are quite simple. They are just small sticks that are cheap to manufacture. These sticks have a special receptacle where the patient needs to add a drop of their blood, which is often drawn from a finger. Now, in the stick's surface there is a white background. As illustrated below (Figure 4), if the quantity of the blood sample is adequate, one line will appear at a specific area of the white background. Following that, another line will appear at another specific area in case immunoglobulin M (IgM) antibodies exist in the sample. A third line will appear if IgG antibodies exist in the sample. If both IgM and IgG are present, there will be three lines in total. All these happen within about fifteen minutes. However, it seems like these tests are still lacking in accuracy, as there are many reported cases of false negative and false positive results (Li et al., 2020).

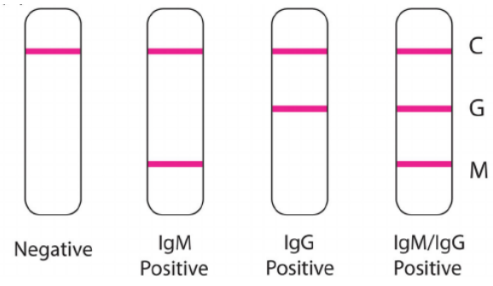

Figure 4. Antibody test(Li et al., 2020).

3.3.2 Antigen tests

Antigen tests are used to determine if someone is infected by the virus at the time of testing. The term antigen refers to certain proteins that exist on the virus's surface. When the human immune system detects them, it creates antibodies that target and bind these proteins and, consequently, the virus. In order to conduct an antigen test, a

nasopharyngeal swab sample is taken from a person. It is mixed with a liquid and then placed on top of a testing device. The way this testing device works is by detecting these proteins (the antigens), which, again, are located on the surface of the virus. For this to happen, a stick shaped device is fashioned, on top of which there are immobilized antibodies of the virus that react with the specific proteins, resulting in the latter's detection by the device when the virus is present in the liquid. Thus, due to the detection of the protein, the existence of the virus is considered to be confirmed. The manufacturing of an antigen test is considered easy and the overall process of making and performing the test is much cheaper than a RT-PCR. However, the disadvantage of this method is that it does not amplify the copies of the virus present in the sample, like the RT-PCR does. As a result, the antigen test is not working in cases where the individual has a low viral load. In other words, the antigen test's disadvantage is that it is expected to generate some false negative results (Dinnes et al., 2021).

3.4 Conclusion

A key conclusion we can draw from the RT-PCR section is that this method makes sense when principally used for testing and not for screening. This is because it is difficult for a citizen to pay for and, also, engage in the time-consuming process of RT-PCR without any indication they are ill. As far as states are concerned –which are the main test providers– it seems absurd to have the large amount of money required by RT-PCR to perform screening tests on a satisfactory part of the population. Even if the cost is excluded, it is difficult to find specialized staff (and infrastructure) in such numbers.

An additional conclusion is that with ready-made kits it is much easier to perform the method, as they require less steps and time. However, using a ready-made kit can create the illusion that, due to its simplicity, not many proffesionals need to be involved in PCR. As a result of this illusion, mistakes are made. For example, as described earlier for the RT-PCR procedure, this involves primers. But primers are sequences of RNA which may be short but, during the procedure, they are amplified. The result is that, after (usually) 40 cycles of amplification, they can be misread as virus RNA. In this case, they need someone with sufficient knowledge to interpret the result or, at least, the suspicious sample has to be checked again – something that rarely happens, due to its cost. One final conclusion is that a) due to its efficiency b)

due to its high cost and c) due to the emphasis given to it by government agencies, RT-PCR is largely presented as an authoritative test that decides who is sick and who is not, creating strong socio-medical roles.

Regarding antibody tests, it seems that their ideal use is for screening a part of the population, in order to determine how much the disease has spread to a specific geographical area and/or to determine what percentage of this population has antibodies to the virus and is, therefore, (up to a degree) protected. Also, we saw that it is a relatively cheap method that seems to be more friendly to use, since the sample needed is a drop of blood and not nasopharyngeal swabs. On the other hand, it does not seem to show particularly high efficiency.

About the antigen test now, the main reason for which it is considered to be ideal for screening but not for testing is the fact that, on some occasions, it gives false negative results. Because, as explained earlier, in the case of testing, there is a patient who is already ill and the correct diagnosis is crucial. If the test taken is an antigen test and it mistakenly indicates that the patient is not sick by the virus, this means that even their life could be in danger. Conversely, if the test mistakenly indicates that a person is sick by the virus when they are not (like the RT-PCR sometimes does), this is also important but not such a big deal, as they will probably undergo further examination. On the other hand, as already explained, in screening the totally opposite should happen. There is need for cheap mass diagnosis, so it is considered better to have a tendency to generate false negatives rather than false positives and, hence, the antigen test is preferred (Ruf et al., 2017).

4. General Overview

At this chapter an attempt will be made to systematize the information resulting from the previous chapters. We will try to clarify some issues and through them to formulate the research questions that will guide us through the second part of the thesis.

Nowadays, the most popular opinion among engineers is that when something needs to be tested, certain methods must be formulated and certain devices must be manufactured. Then, the politicians decide which one to use on each occasion. However, as we have already seen, such an approach might not be necessarily

satisfactory. So far, it should have been made clear that there are different testing policies that have been implemented – like solely relying on either diagnostic testing or medical screening or, also, using a combination of both. In addition, we have seen that even during their design, the devices manufactured seem to entail a specific policy. Thus, the first thing that needs to be examined is whether the realization that testing methods and devices are political entities can assist us in using these exact devices in more effective ways.

In the case of testing, we saw that its purpose is the effective diagnosis of a patient who exhibits symptoms, no matter the cost and the time needed. That is, someone who is ill turns to health professionals and asks for a diagnosis. What is needed in this case is a reliable method that health professionals can use to understand (with a small margin of error) if the patient is suffering from this virus. As explained earlier, in terms of margin of error, there is a preference for false positives over false negatives. The RT-PCR method seems to be ideal for this work. The RT-PCR was not designed for the Covid-19 pandemic, but was adjusted by adding one more step to the method (i.e., the conversion of RNA to cDNA) and found an excellent application in testing for this particular virus. If approached from a somewhat different perspective, the RT-PCR method seems to be the regulator of everything. It is the most reliable method, has existed for years and uses the most expensive reagents and the most well-trained professionals. Even the fact that all the other methods calculate their efficiency according to their comparison with RT-PCR proves its suitability. RT-PCR is treated as the truth regulator about Covid-19 testing and we have to study how this particular fact creates specific social roles and modifies the social environment directly and on purpose, as Marres and Stark invite us to do (Marres and Stark, 2020).

In the case of screening, we saw that its purpose is the cheap and fast mass testing of people, whether they show symptoms or not, in order to have an approximate view of how much the virus has spread to a specific geographical location or to a group that meets specific criteria (such as age or health status). It is considered normal to have a higher margin of error on that occasion, as the target is to have the approximate idea and not the absolute truth: if the screening produces a wrong diagnosis, the individual will also try a testing technique in case they exhibit any symptoms. Moreover, as explained earlier, in terms of margin of error, there is a preference for false negatives

over false positives. With that being said, antigen tests seem to be ideal for screening. However, if we look back at what Armstrong and Eborall claim about screening (Armstrong and Eborall, 2012), we have to check certain issues concerning antigen tests. First of all, we need to check how clear it is that antigen tests provide a result with a high degree of uncertainty. If the antigen test indicates you are ill there is a high probability it is right, but if it indicates you are not ill, this is not something you should count on. As described before, this degree of uncertainty is very important because it not only creates a so-called "false reassurance" but also affects the level of a screening policy's attendance (Armstrong and Eborall, 2012). Furthermore, a factor that should also be examined is, as already mentioned, the anxiety a screening test can induce and its possible effects.

Another issue that needs to be investigated is the social role of the reliable (or unreliable) person that a test constructs, according to the articles of both Robinson and Armstrong & Eborall (Robinson, 2020)(Armstrong and Eborall, 2012). Especially in the case of screening, whose effectiveness depends upon how many members of the group-to-screen are participating. Therefore, two important questions arise: are the tests reinforcing the concept of a community or are they intruding into the personal life of individuals, creating stress and false obligations? Could it be that they are doing both of these things?

5. Analysis

5.1 Real Time - PCR

The RT-PCR test existed as a diagnostic method long before the Covid-19 pandemic began. Nevertheless, as it is the most used testing method during the pandemic, we have to examine its social impact. At this chapter, the real time PCR method will be discussed. This discussion will be based on published articles that are reviewing this method from a technical perspective. However, we will try to expand this RT-PCR evaluation into an STS evaluation.

According to Tahamtan and Ardebili, "the polymerase chain reaction (PCR) method is considered as the 'gold standard' for the detection of some viruses and is characterized by rapid detection, high sensitivity, and specificity. As such, real-time reverse transcriptase-PCR (RT-PCR) is of great interest today for the detection of

SARS-CoV-2 due to its benefits as a specific and simple qualitative assay" (Tahamtan and Ardebili, 2020). Nevertheless, they claim that there are certain issues with the RT-PCR method. The first of these has to do with the fact that, in some cases, this test does not recognize the virus within a sample and, hence, produces a false negative result. As a result, a negative RT-PCR result does not definitely mean that someone is not a carrier of the virus, even though it is most likely they are not. In fact, there is no 100% accurate test, meaning that even if a test was 98% sensitive and 99% specific, it would still produce a false negative result in two of every 100 people that were tested while infected (Shuren and Stenzel, 2020). Moreover, providing a false positive result is more usual for the RT-PCR than providing a false negative. This is because, in order for the method to function, some primers are placed within the input liquid. These primers are strands of RNA, so even if there is no RNA in the sample, after a few RT-PCR circles, the primers will be amplified and they could be misunderstood as the virus. These issues were highlighted at the paper by Tahamtan and Ardebili published at 22 April 2020 (Tahamtan and Ardebili, 2020). Regarding the false negative results, it seems like some technical progress has been made. Even by November 18, 2020, Zhou and his colleagues claim that: "[t]heoretically, real-time PCR detection is widely used as the molecular diagnosis standard for SARS-CoV-2", so they suggest a strategy to reduce false negative results provided by RT-PCR kits (Zhou et al., 2020). The specific issue remains a matter of discussion. Someone can observe this in various publications, like the one by Lascarrou and his colleagues published on 27 January, 2021, who insist that "[s]trategies involving serial RT-PCR testing must be rigorously evaluated." (Lascarrou et al., 2021).

Things get even worse if someone tries to use RT-PCR as a screening method. This is due to the high cost of using this method for each separate sample (Du et al., 2021). That high cost of using RT-PCR for each separate sample is the reason that another method is frequently used, which uses RT-PCR for the analysis of multiple samples at the same time, a strategy called pooled sample testing. According to the Food and Drug Administration (FDA), this strategy involves mixing more than one samples into a pooled sample and then test the pooled sample with RT-PCR. This approach increases the number of individuals that can be tested using the same amount of resources but, because the samples are diluted (which could result in less viral genetic material available to detect), there is a greater likelihood of false negative results

(FDA, 2020). Atul Garg and his colleagues have evaluated some RT-PCR kits regarding their ability to analyze pooled samples. They examined seven of the most popular commercially available kits. After their experiments, they found that all seven kits were able to detect coronavirus in samples that contained a high concentration of the virus. However, three of the kits were generating false results on samples that contained a low concentration of the virus. That means that some of the commercially available kits sometimes cannot detect the presence of the virus in samples from people that have a low viral load (Garg et al., 2021).

Yet, why should one worry about a few false negative results from an otherwise very effective method? First of all, as described in the first part of this thesis but also in the articles cited above, RT-PCR is definitely a testing method. Actually, it is the golden standard of testing methods during the Covid-19 pandemic. Therefore, as already described, being a testing method, RT-PCR should be as accurate as possible. It is supposed to be used mainly by people who are already ill, in order to learn if they are sick because of the virus or due to something else. If every now and then this method is providing a false result, it is preferable that it has a tendency towards a false positive rather than a false negative. All this criticism of the RT-PCR method seems to be rational if someone supposes that the method is politically neutral and, as such, can be integrated in all testing policies. In that scenario, the specific method should be able to produce absolute results and eliminate any chances of error.

However, that is not the case. In this thesis it is argued that testing methods are not politically neutral and, hence, get along well with specific policies. For instance, the RT-PCR method is a testing method and, thus, not designed for screening. Its intended use is for people that are already ill and go to the hospital for an accurate diagnosis. These people normally have a high viral load. Thus, the probability of the RT-PCR providing them with a false negative result is extremely low. On the contrary, when RT-PCR is used for screening, the false negative results are significantly increased.

But why resort to the RT-PCR method for screening, since much cheaper, easy to use and rapid techniques exist? The answer is not technical. According to our perspective, this mostly has to do with what was previously detailed: the RT-PCR results are considered absolutely truthful and the test itself is the regulator of overall testing

during the pandemic. From reviewing Marres and Stark's approach to testing it becomes evident that the RT-PCR method modifies the social environment during the Covid-19 pandemic. This happens by categorizing people into those who have taken the RT-PCR test (and, hence, are free of the virus) or those who tried another test (and, hence, are possibly but not certainly healthy) and those who have not taken a test (and, hence, are possible carriers of the virus). Therefore, RT-PCR indicates who you should hang out with and who to avoid in order to stay healthy. It also indicates which tests you should trust, as all tests –like the ID NOW COVID-19 test, which will be analyzed in the next section (Tu et al., 2020) - are compared to this. Moreover, since there are various forms of governance during the pandemic (as detailed in the introduction), it is understandable that not all of them are based on good information of the people and on a rational use of the testing methods – like it happened in South Korea (Shaw et al., 2020). Consequently, some governments may use methods like RT-PCR (which people perceive as trustworthy) and, taking advantage of the lack of public awareness around these issues, may enact policies that seem to be irrational and unpopular – for instance, constant lockdowns. Additionally, it is important to keep in mind the test's psychological impact, as Armstrong and Eborall have detailed it (Armstrong and Eborall, 2012). The RT-PCR method seems to particularly increase people's anxiety, as it requires a lot of time to yield a result. During that period, individuals may become anxious of the social role they will be assigned with. Furthermore, when ill-advisedly used as a screening method, RT-PCR may create the false reassurance we have spoken of because someone may interpret the negative result as an accurate diagnosis.

Here, it might be appropriate to underline what Michael J. Mina and his co-authors maintain: "it's time to change how we think about the sensitivity of testing for Covid-19" (Mina et al., 2020). Even though some methods exhibit the highest sensitivity possible, the rapid spread of the virus requires tests that can be performed many times. Therefore, they should be cheap, fast and easy to use.

5.2 Abbott Laboratories Rapid Tests

This section presents an analysis of some rapid SARS-CoV-2 tests produced by Abbott Laboratories. The reason the specific products were chosen is because of the early timing of their development and their popularity, as they probably are the most frequently used rapid tests worldwide – at least until the time this thesis was being

composed (June 2021). The main focus will be given to two specific tests made by Abbott Laboratories, a molecular and an antigen test. Through the examination of the tests as political entities, it will be attempted to answer some of the questions that have been asked so far. The analysis will be based on the review article of Wudan Yan & David Schneider "The race for a here-and-now Covid-19 test" (Yan and Schneider, 2020), as well as some Abbott Laboratories articles concerning its products.

5.2.1 Abbott's ID NOW COVID-19 test

In this subsection it will be argued that Abbott Laboratories' ID NOW COVID-19 test is not a politically neutral device, as it might be purported. Up until a certain point of the pandemic, Abbott's ID NOW used to be the most famous Covid-19 rapid test, at least in the United States. Of course, that is because it was also the one used at the White House.

ID NOW was introduced in 2014 and its then use was to detect influenza strep A and the respiratory syncytial virus (Yan and Schneider, 2020). As illustrated in the figure below (Figure 5), ID NOW's recent version is functioning as a rapid RT-PCR method. Like in the case of the RT-PCR, a swab sample is taken from an individual, it is mixed with a liquid and, next, it is inserted in a "black box" – like the ones of the fully automated RT-PCR kits. Then, the box amplifies the RNA existing in the liquid and tries to detect the coronavirus's genetic material. After a short period of a maximum of 13 minutes, the box decides whether the individual is positive to the virus or not. What is important to underline is that, even though it was introduced in 2014, ID NOW has not been FDA cleared or approved. It has been authorized by the FDA under an emergency use authorization for use by authorized laboratories and patient care settings. The test has been authorized only for the detection of nucleic acid from SARS-CoV-2 and not for any other viruses or pathogens (Abbott Laboratories, 2020a).

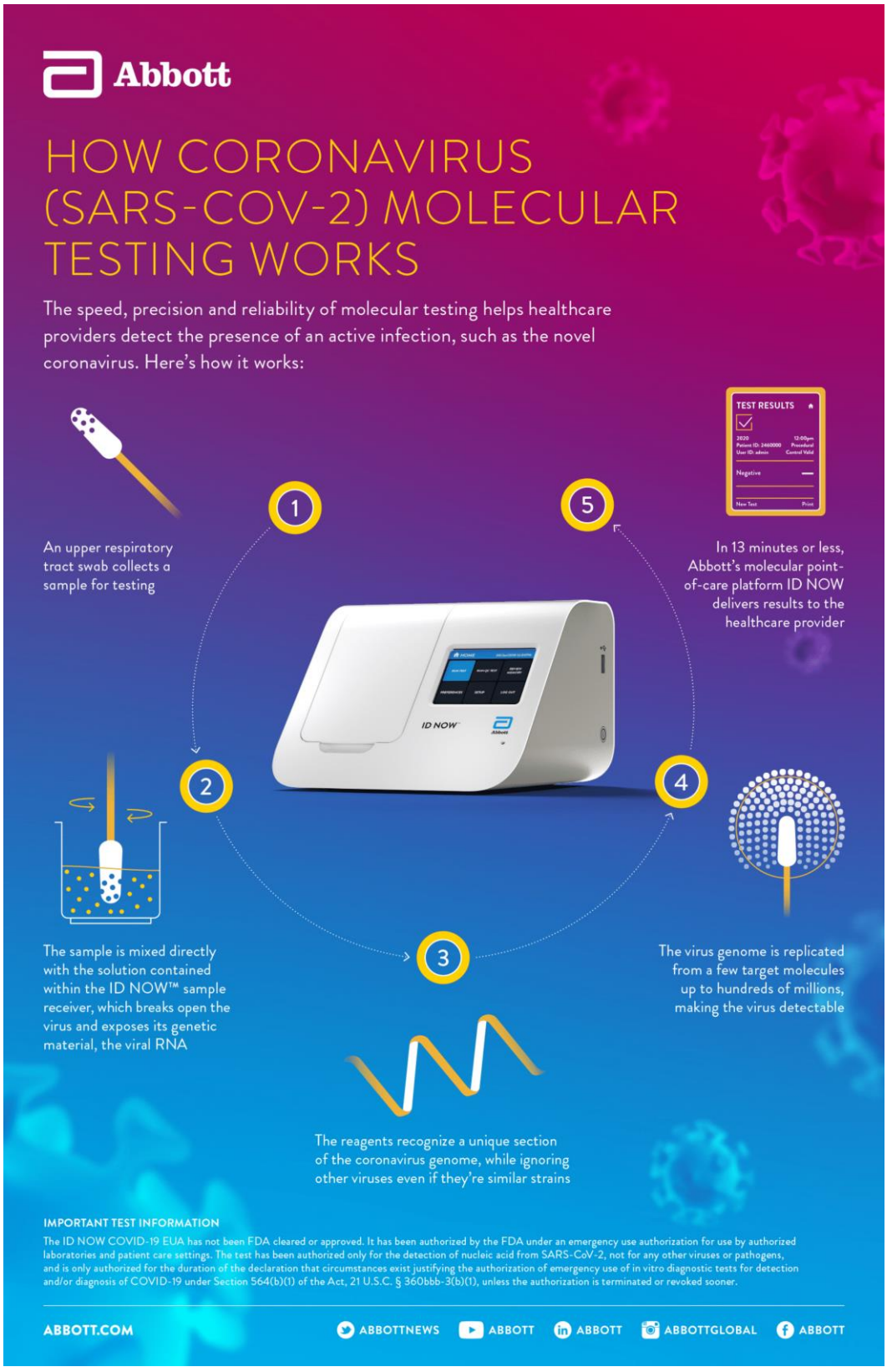

Figure 5. How the ID NOW COVID-19 test functions. (Abbott Laboratories, 2020a)

ID NOW is characterized by Abbott Laboratories as portable, reliable and rapid, with results produced on the spot – all in the size of a toaster device (Abbott Laboratories, 2020a). However, these claims need to be scrutinized.

For sure, the ID NOW device is portable (as its dimensions actually approximate those of a toaster), it is fast and it indeed provides results on the spot (as the sample does not need to be moved to a laboratory). What is not mentioned by Abbott Laboratories is its high price and the fact that it is using expensive reagents for each single test. That needed to be noticed before we start discussing its reliability. When it is asserted that this is a reliable device, regarding which exact function is it meant to be reliable? On the first part of this thesis, we have already seen that there are different applications for a test – like whether it will be used for testing or screening. These applications necessitate different characteristics in order to declare a device reliable. So, first of all, there is a need to clarify if ID NOW is used for testing or screening.

Abbott Laboratories claims that ID NOW can be used both for testing and screening. As they state: "That result not only allows healthcare providers to appropriately screen the patient for treatment, but it can also detect the SARS-CoV-2 virus after exposure to help diagnose COVID-19" (Abbott Laboratories, 2020b). But is that true? Testing and screening give rise to different policies, so can a device be politically neutral and utilized in different policies?

As it has been previously noticed, when speaking of rapid tests, we usually speak of screening. However, it has been stressed that screening demands a relatively cheap method –something ID NOW is not– as it has to be repeated numerous times in order to test a specific portion of the population. So, up until this point, the company's assertion is somewhat confusing. The next step is to check if there is a tendency for false negatives (which would indicate it is appropriate for screening) or false positives (which would indicate it is appropriate for testing). According to Abbott Laboratories itself (Abbott Laboratories, 2020b), the ID NOW has a good but not excellent sensitivity of 91.3% and an excellent selectivity of 100%. There also are some reported false negative cases, which would indicate screening. Something that would also indicate screening is the fact that they do not mention the limit of detection,

which could lead one to believe that the device cannot recognize the virus when the viral load is low.

The manufacturers have additionally noted where the device is mainly used, which is something we need to take a look at. Specifically, the manufacturers state: “ID NOW has quickly become an important tool in the fight against COVID-19 outside of traditional hospital settings.

- Some hospitals use it to test patients before surgery.
- People who need chemotherapy and are behind in their treatments are now able to be tested quickly so they can get back to the hospital to continue on their journey to recovery.
- Urgent care centers and pharmacy clinics are using the test in point-of-care sites throughout the country.” (Abbott Laboratories, 2020a)

Thus, it is obvious that ID NOW is used both for testing (since, for example, hospitals rely on it for the crucial diagnosis) as well as screening (since it is used in point-of-care sites throughout the United States).

In conclusion, it seems that the ID NOW Covid-19 test is indeed a political entity. It has been intended as a rapid alternative to RT-PCR that provides results on the spot. Due to that, it has been designed to test a large number of people in a short period of time, providing good but not excellent results (which have a tendency towards false negatives). In short, ID NOW fulfills all the criteria we set at the first part of the thesis for what a screening method is, except for the fact that it is not sufficiently cheap. Therefore, ID NOW does not give the impression of a politically neutral device that can be integrated in every testing policy, as Abbott Laboratories seem to imply. On the contrary, even by its design, ID NOW is linked to a screening policy and does not appear to be appropriate for testing – especially since there are better methods for it. In addition, as we know, ID NOW was used at the White House for testing a large number of visitors in a short time – therefore, it has been used as a screening technique. Thus, even though the US government seems to know that ID NOW is best suited for a specific policy and they use it as a part of that policy, at the same time they allow this device to be considered politically neutral and be used across the country in any way someone desires. Furthermore, it is interesting to mention that

because it is not clear that ID NOW is a screening device, its (mistaken) use in the White House did not work out, as federal officials relied too heavily on the tests and then took the results for granted (Wu, 2020).

5.2.2 Abbot's BinaxNOW Ag Card

As described in the first part of the thesis, even though antigen tests are considered to be ideal for screening, their strong disadvantage is their low efficiency. It is normal for screening tests to provide some false negative results, but up to a point. That is why the need to develop more effective antigen tests has been emphasized.

According to Wudan Yan & David Schneider's article published on October 2020, what the world desperately needed then was a way to diagnose viral infections more quickly and easily. Because of that, they expected a lot on the front of the development of new antigen-based tests. Especially, they believed that these tests should do three things: detect the antigens of the virus effectively, in a short time and in an easy way. Having said that, they focus mainly on a specific incident: FDA's emergency-use authorization of an Abbott Laboratories test which they considered to be near-ideal – the so called BinaxNOW Ag Card (Yan and Schneider, 2020).

The BinaxNOW Ag Card obtained an emergency use authorization from FDA on 26 August of 2020. Again, this is a rapid test from Abbott Laboratories, which requires 15 minutes in order to provide a result. However, BinaxNOW is much simpler and cheaper than ID NOW. As explained in previous chapters, what the antigen tests do is recognize the virus antigens – which are the proteins on the surface of the virus. BinaxNOW is, essentially, just a card (at the size of a credit card), which has the ability to detect coronavirus antigens when it comes in contact with the virus. The whole procedure involves taking swabs from one's nose, mixing them with a liquid and, at the end, placing the medium on top of the card. Then you just wait for 15 minutes and the test provides you with an answer. If one line is formed on the test surface, the test is negative to the virus, whereas if two lines form, the test is positive to the virus (Abbott Laboratories, 2021a).

As mentioned above, BinaxNOW is simpler and cheaper than ID NOW. However, what seems to be interesting is the fact that, in the case of BinaxNOW, Abbott Laboratories states clearly it is designed for medical screening. While they do not use these exact words, they however assert the following: "Now, with BinaxNOW

authorized for over the counter for frequent asymptomatic use, we are making testing directly available for fast results, when and where you need it" (Abbott Laboratories, 2021b). They also claim that "Rapid antigen tests such as BinaxNOW are able to quickly identify individuals with or without symptoms or other epidemiological evidence to suspect COVID-19 infection within minutes and enable fast isolation, as opposed to waiting days for a lab result" (Abbott Laboratories, 2021c). Furthermore, when providing the specifications of the test, they calculate the –good but not excellent– sensitivity of the method only for the infectious individuals tested and not for all the individuals that have even a minimal viral load according to RT-PCR (Abbott Laboratories, 2021c). In other words, it is obvious that they consider the specific test as a method compatible only with pandemic response policies that are based on screening.

However, this is not its only difference from ID NOW. BinaxNOW is a rapid Covid-19 test designed to be used by individuals, without the presence of a healthcare professional being necessary. According to Wudan Yan & David Schneider's article published on October 2020, BinaxNOW is innovative because it will allow places like schools and workplaces to function better (Yan and Schneider, 2020). As late as the spring of 2021, we can see that these are the fields on which Abbott focuses for using the specific test. On their YouTube channel they have even uploaded manuals and videos about how to perform the test yourself (Abbott Laboratories, 2021a). Additionally, their documents that are addressed to parents reassure them about the policy of schools to reopen by relying on BinaxNOW (Abbott Laboratories, 2021d).

This aspect of medical screening seems to perfectly fit the scenario Kelly Joyce has described for biomedical imaging. According to it, biomedical devices and methods leave healthcare professionals behind and can even be found at malls, in order for people to use them themselves (Joyce, 2010).

In addition, through a review of the sociology of testing, we can detect a match between this aspect of using BinaxNOW and the issues raised at the second chapter of this thesis. According to Marres and Stark, when the test is carried out uncontrollably in society, its effects and results are significantly different compared to when it is carried out in the lab. Therefore, it can be assumed that self-testing will modify the social environment directly and on purpose (Marres and Stark, 2020). How exactly it

will modify the social environment we cannot yet know, but we can speculate about it.

For example, we replace a pregnancy test with BinaxNOW, as suggested in Robinson's analysis (Robinson, 2020). BinaxNOW tests for sure if you are positive to the virus or, put differently, if you are infectious. However, it also tests your responsibility – i.e., it tests if you are a responsible citizen, caring for the common good by doing regular checkups. Similarly, a pregnancy test might imply whether you are a good parent who makes sure their kid will not be left untested. Additionally, it tests your social relations (as self-testing also does): for instance, before going for a walk with a friend, you can demand they take the test.

In any case, we can now see that BinaxNOW is not just a testing method used to combat the spread of the virus, but also has a political substance. Not only does it go along only with policies based on screening (like ID NOW), but also goes a step further. It is designed in a way that obliges the citizens to be responsible for their own health. It removes a big part of the government's responsibilities regarding public health and places it on the citizens' shoulders.

Since this policy is discussed, it is worth mentioning that Armstrong and Eborall (Armstrong and Eborall, 2012), have wondered about its psychological dimension: what about the stress created? This stress is not only induced by getting screened but, more than that, by having to be the one to screen yourself. Not only you have to "pass" the test, but you also have to make sure that the test will be carried out correctly.

Last but not least, in the cases of both ID NOW and BinaxNOW, there is another serious political aspect. Both these devices, in order to be effective, are only compatible with a policy that ensures a high rate of citizen attendance. If a sufficient percentage of the population does not attend the screening, it is hard for the government to track the virus and effectively deal with it (Marres and Stark, 2020). This fact means that the government will either just try to better inform the public or, alternatively, place the responsibilities on citizens' shoulders –something that seems to have happened in many European states– or, even, force citizens to participate by taking stricter measures – something that seems to have happened in China (Shaw et al., 2020).

5.3 Antibody test

This section examines the Covid-19 antibody tests. The analysis will be based on articles that dissect some of these tests from a technical perspective. An attempt will be made to expand this analysis into an STS one. A lot can be said about the Covid-19 antibody test. As explained in the first part of this thesis, antibody tests seem to be a screening method and are ideally used to determine how much the disease has spread to a specific geographical area or what percentage of the relevant population has developed antibodies to the virus and is, therefore, up to some degree protected.

Ejazi, Ghosh and Ali believe that, until a huge percentage of the population has been vaccinated, it is extremely important to develop tests that are cost-effective, simple and suitable for large-scale testing and surveillance (Ejazi et al., 2021). They claim that antibody tests can play this role. However, what seems to be interesting is that by reading their article "Antibody detection assays for COVID-19 diagnosis: an early overview" one realizes the political underpinnings of these testing methods. First of all, in a way they admit that antibody tests (and rapid tests in general) can be integrated into screening policies and not in testing, after their comparison to RT-PCR. More particularly, they claim that "[w]hile RT-PCRs are good options for detecting the virus, their cumbersome protocols, time and expense do not make them suitable candidates for mass testing, emphasizing the need for alternative tests. Rapid tests are quintessential for detecting a mass population because of their ease of use, less time consumption and low cost, and thus may be used complementary to RT-PCRs largely for the false-negative case detection in symptomatic cases. Unlike RT-PCR, rapid tests have their limitations in terms of performance and sensitivity." (Ejazi et al., 2021). Actually, Zhengtu Li and his colleagues come to a similar conclusion. According to their research concerning Covid-19 antibody tests, they claim that the combined IgM-IgG antibody test can be used for the rapid screening of SARS-CoV-2 carriers (symptomatic or asymptomatic) in hospitals, clinics and test laboratories. Still, in a different part of their article, they compare the combined IgG-IgM antibody test to separate IgG and IgM tests and, concerning the first of these, they state that "[i]t is a better test for screening COVID-19 patients." (Li et al., 2020). It is then made clear that, according to their point of view, an antibody test is not neutral but, rather, goes along well with screening policies.

Remaining on this article by Ejazi, Ghosh and Ali (2021), it is important to note that the authors claim antibody tests are useful because they can accomplish large-scale testing and surveillance. However, large-scale testing and surveillance is a specific policy that is not followed by every country. Actually, if we return to the article about the different forms of governance, we can easily realize it is a policy followed by countries like China (Shaw et al., 2020). In these countries, screening techniques play a major role, as they are integrated in the large-scale testing and surveillance policy. Nonetheless, other countries follow different policies, which require different methods.

"*The world cannot be kept at a standstill and lockdown for an indefinite period waiting for a vaccine*" Ejazi, Ghosh and Ali proclaim at another part of the article (Ejazi et al., 2021). However, this statement is, again, political. It proves that antibody tests are useful for a country that does not want a constant lockdown. This is a political choice, as there are countries that prefer a policy with a constant lockdown, in which policy the antibody tests are not so useful. For example, the Greek government opted for a constant lockdown until a significant percentage of the population has been vaccinated (FT Visual & Data Journalism Team, 2021).

Last but not least, the uncertainty of the antibody tests needs to be examined. Here it should again be stressed how important the level of uncertainty for a screening technique is, according to Armstrong and Eborall. In their point of view, a high level of uncertainty in the method not only increases the false results provided –which, as discussed before, creates the problem of false reassurance– but, also, increases people's suspicions towards the screening test. This factor, as already noted, strongly affects the attendance level – something crucial for any screening technique (Armstrong and Eborall, 2012). Thus, when the uncertainty of the antibody test is examined, things do not seem to be in favor of the tests. In addition, there are reports of cases (like the one in the UK) where the results from the governmental evaluation of the tests were not disclosed to the public (Mahase, 2020). Even in the case of the ones that have been publicly evaluated, it seems that the level of uncertainty is too high. Therefore, professionals cannot rely on antibody tests to return to work (Maple and Sikora, 2021).

6. Conclusion

In this thesis I have argued that technology is not politically neutral, by showing how specific technological devices –i.e., the tests used during the Covid-19 pandemic– are not neutral. On the contrary, specific policies are integrated into the design and function of each testing method.

In order to demonstrate this, various STS approaches were discussed, including Marres and Stark's opinion on how testing modifies the social environment, Robinson's opinion on how testing creates social roles and Armstrong and Eborall's opinion on screening, its impact to society and, even, its psychological parameters. From those theorizations arose the separation between testing and screening, as well as some of the main questions set forth in this thesis. Next, the operation of the main devices used for testing and screening was analyzed. Namely, the devices scrutinized were the RT-PCR method used for testing and the antigen or antibody tests used for screening, by referring to technical articles but, also, to articles by the manufacturing companies themselves.

From the analysis of these articles it firstly became obvious that the existing methods lead states to the adoption of specific policies. In more detail, we saw that certain mass screening techniques presuppose the existence of strict surveillance and control of the population in order to be effective. Additionally, they presuppose a high percentage of participation in the method on the part of a country's population. In contrast, policies based on expensive and time-consuming but highly effective testing methods usually presuppose a long-lasting lockdown, as the states cannot adequately control the spread of the virus. Finally, policies that combine testing and screening presuppose an informed citizenry, so that each method is applied where it is most effective.

Moreover, it also became obvious that testing methods modify the social environment. Specifically, we saw how the RT-PCR method, which is the golden standard of testing, modifies the social environment during the Covid-19 pandemic by categorizing people into those who have taken the RT-PCR test –who, unless they tested positive, are free of the virus– and those that have not taken a test – who are likely carriers of the virus. We also saw how it separates other tests into trustworthy and untrustworthy ones, as they are all compared to the RT-PCR. In addition to all

these, the stress caused by awaiting the results of the time consuming RT-PCR must be underlined. On the other hand, screening methods also modify the social environment, as they presuppose a high level of attendance, which, sometimes, is undermined by their relatively low efficiency. Specifically, they actively foster a sense of individual responsibility and create different roles, such as that of the responsible individual who participates in screening and the irresponsible individual who does not. As we have seen in the case of BinaxNOW, this phenomenon becomes more intense when the functioning of schools depends on self-testing screening techniques (which adults and their children have the responsibility to perform regularly). As before, these methods can also be stressful to those who participate in them.

Finally, it is concluded from this thesis that the testing and screening methods employed during the Covid-19 pandemic are political entities that affect how a country is governed. In addition, to some extent, they shape the social environment and, also, affect the psychological state of people on an individual level. We furthermore realized that the sociological analysis of techniques used by engineers and doctors can optimize their results when they are applied to society and reduce some of their malfunctions.

As the Covid-19 pandemic is still in its infancy, no very specific conclusions could be drawn. However, this critical task should be eventually carried out, so that any definitive findings can be used to combat future pandemics. In particular, it would be worthwhile to delve into a more detailed analysis of the specific governance models followed by different countries and the relation each model has to the testing and screening methods used. A final interesting issue (which was not considered in this thesis) has to do with how each method of testing or screening affected the lives of particular groups (with regard to age, gender or special health status).

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